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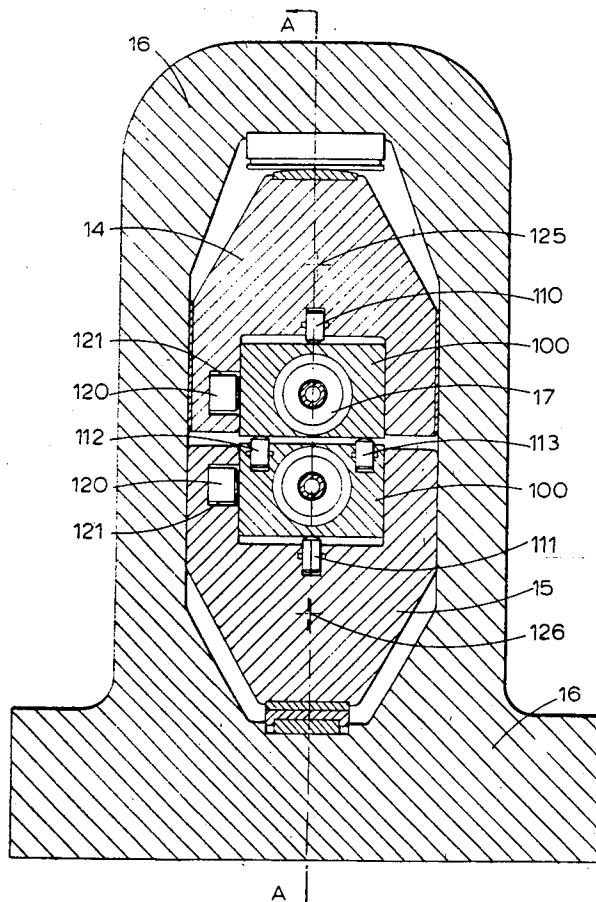
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[54] **STOCK TENSION CONTROL IN ROLLING MILLS**
18 Claims, 5 Drawing Figs.

[52] U.S. Cl..... 72/21
[51] Int. Cl..... B21b 37/06
[50] Field of Search..... 72/21, 12,
237, 245, 246, 247; 73/159

ABSTRACT: A rod or bar rolling mill stand wherein the two work rolls are each mounted on a free end of, and driven by, a respective work roll drive shaft. A common axis is defined extending perpendicular to and displaced from the stock pass line. The common axis intersects the shaft axes at points fixed on the shafts. The shafts are pivotally movable about the common axis. Load sensing devices are disposed acting between each shaft and the mill frame, whereby the devices give signals representative of the stock tension adjacent the mill stand.



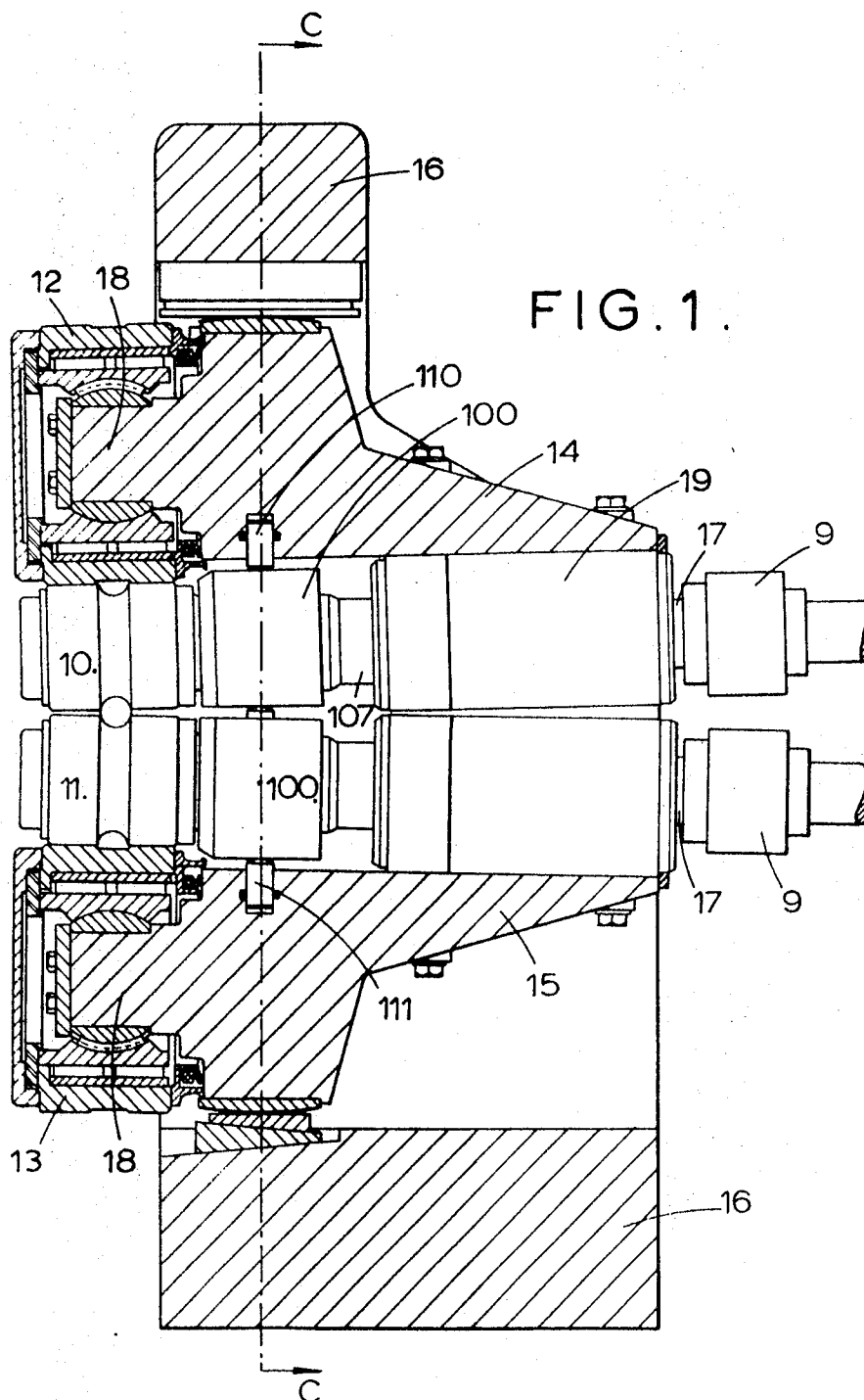


FIG. 1.

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FIG. 2.

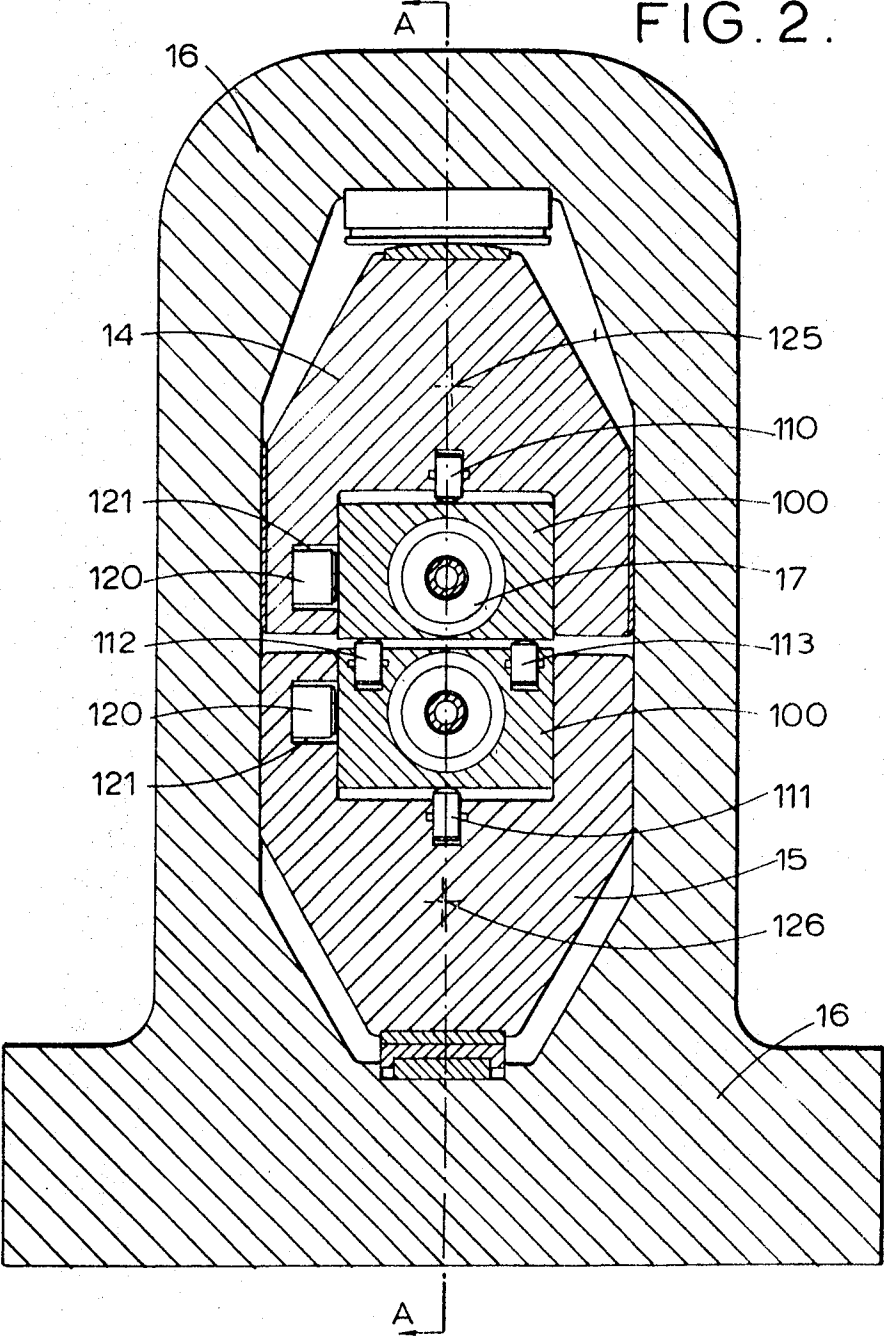
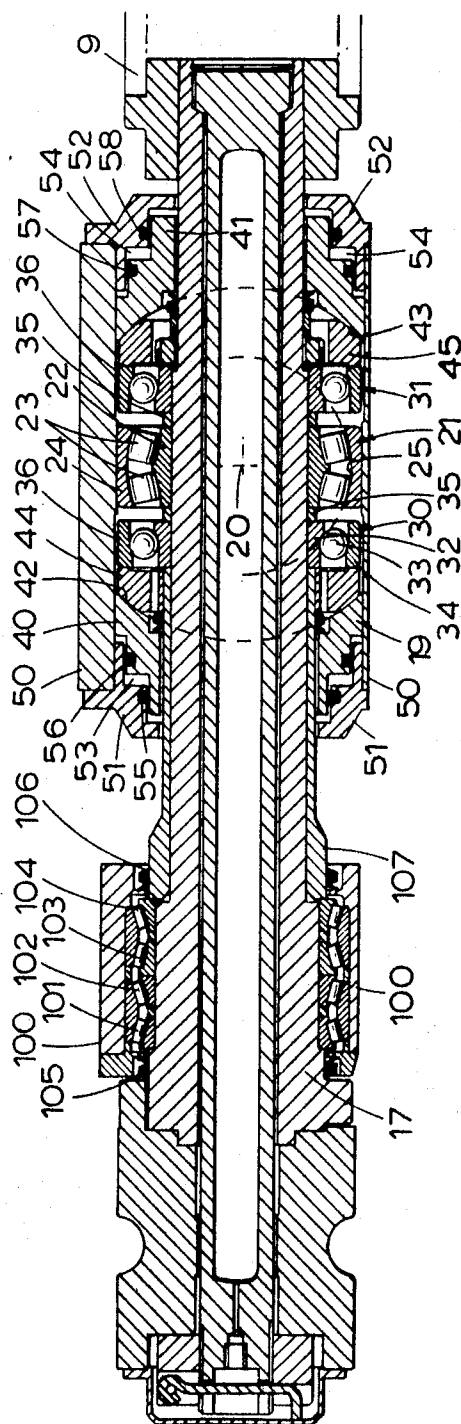


FIG. 3.



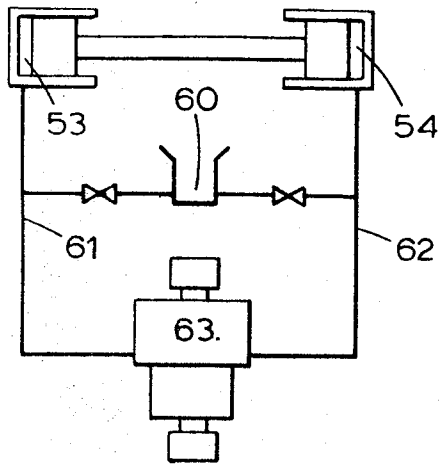


FIG. 4.

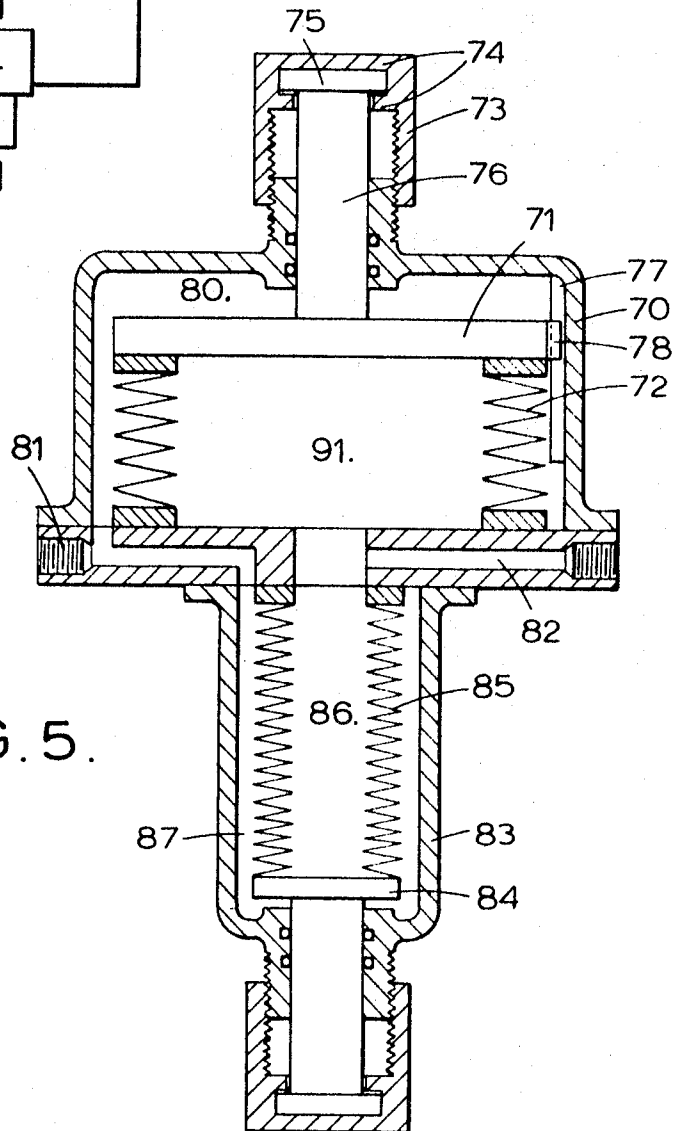


FIG. 5.

STOCK TENSION CONTROL IN ROLLING MILLS

This invention relates to rolling mills, and particularly but not exclusively to rod or bar stock rolling mills.

In bar or rod stock rolling, for instance, in a steel mill, the width and height of the bar leaving the final roll pass depends to a certain extent on the tension of the stock between the final roll pass and the penultimate roll pass, and the tension between the penultimate roll pass and the previous roll pass as well as the tension after the final roll pass in some cases. Therefore if the height and width of the stock leaving the final roll pass are both to be maintained within close limits of a desired value, it is desirable to control the tension between adjacent roll passes and in some cases after the final roll pass. In order to achieve this it is necessary to measure the stock tension at those points and adjust the rolling process so as to continuously correct the stock tension to a predetermined desired value.

If such adjustment is to be effective, particularly at the high rolling speeds associated with small cross section stock it is important that the means provided to measure the stock tension has a high frequency response and that the means utilized to correct the stock tension is also of a similar response.

It is therefore an object of the present invention to provide means on a rolling mill stand, particularly, but not exclusively for use on final or penultimate passes, by which the stock tension adjacent that stand may be measured.

It is a further object of the present invention to provide means for correcting the stock tension in response to detection of stock tension variations from a desired value at a point adjacent a mill stand.

According to the present invention there is provided a rolling mill stand comprising two work rolls rotatably and drivably carried on a frame, at least one of said rolls being carried on a shaft mounted on the frame to be pivotable to a limited extent about an axis perpendicular to and displaced from the line taken by stock passing between said work rolls, and wherein a load sensing device is provided between said work roll shaft and said frame, said device providing in use a signal embodying a measure of the tension in the stock adjacent said mill stand.

Said shaft is preferably mounted on the frame to be pivotable to a limited extent in any direction about the point of intersection of said axis and the shaft axis.

Said shaft is preferably rotatably mounted in bearing means which are preloaded, self-aligning, and which locate the shaft both axially and radially, while permitting pivotal movement about said point, and axial adjustment of the shaft position.

The load sensing device is preferably disposed between a self-contained shaft bearing block and said frame.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a vertical sectional view of a four-high rod or bar mill according to the invention, the section being on line A-A of FIG. 2,

FIG. 2 is a vertical sectional view on line C-C of FIG. 1,

FIG. 3 is a longitudinal section through the work roll shaft and shaft mounting assembly of the mill of FIGS. 1 and 2,

FIG. 4 is a sectional view of a hydraulic control system used in the mill, and

FIG. 5 is a cross-sectional view of a control for the hydraulic system of FIG. 4.

Referring to FIGS. 1 and 2 there is shown a four-high rod or bar mill comprising a pair of work rolls 10 and 11 backed up by supporting rolls 12 and 13. Rolls 10 and 12 and rolls 11 and 13 are carried respectively on two mutually pivotable mill frame arms 14 and 15 mounted on the mill frame 16 as disclosed and claimed in our copending Pat. application Ser. No. 775,668 of even date herewith entitled "Rolling Mills."

The work rolls 10 and 11 are mounted for rotation on work roll shaft 17 and the supporting rolls 12 and 13 are mounted for rotation about stub axes 18. The manner in which the work rolls 10 and 11 are mounted on shafts 17 is more fully

disclosed and claimed in our copending Pat. application Ser. No. 775,840 of even date herewith entitled "Mill Roll Mountings." The shafts 17 are driven by electric motors through reduction gearing and through universal joints shown schematically at 9.

The work roll shafts 17 are each borne at their end portion remote from the associated work roll in a bearing assembly 19 shown in detail in FIG. 3. This bearing assembly is preloaded, self-aligning, locates the shafts 17 both axially (i.e. for thrust) and radially, while permitting limited universal pivotal movement of the shaft about point 20 and also permitting limited adjustment of the axial position of the shaft relative to the mill frame arm. The manner in which the bearing assembly achieves these objectives will now be described in more detail.

The central portion of the bearing assembly 19 comprises a spherical roller bearing 21 consisting of an inner race 22, barrelled rollers 23, and an outer race 24 having an inner face 25 which is part spherical about point 20. It will be appreciated that this spherical roller bearing permits universal pivotal movement of the shaft about point 20 and also provides radial location for the shaft.

Two opposed angular contact ball bearing assemblies 30, 31 are disposed on the shaft one at each side of the spherical roller bearing 21. Each assembly comprises an inner race 32, balls 33 and an outer race 34. The inner races 32 are spaced from the spherical roller bearing 21 by thrust transmitting spacing collars 35. The outer races 34 have clearances 36 from the mill frame arms to permit the limited pivotal movement about pivot point 20. It would be appreciated that the assemblies 30, 31 provide axial or thrust location for the shaft 17.

The bearing assembly is rendered self-aligning by virtue of opposed bearing blocks 40 and 41 disposed at the axially outer sides of ball bearing assemblies 30, 31, the blocks 40 and 41 having bearing surfaces 42 and 43 lying in a common sphere centered on point 20. The blocks 40 and 41 are spaced axially from the outer races 34 of ball bearing assemblies 30 and 31 by bearing spacer collars 44 and 45 having bearing surfaces engaging bearing surfaces 42 and 43. The axial lengths of spacer collars 44 and 45 and spacer 35 are so chosen that surfaces 42 and 43 lie accurately in the common sphere while balls 33 are trapped in a thrust transferring manner between their races 32 and 34.

The bearing blocks 40 and 41 are slidably received in bearing block guides 50 secured to or preferably forming part of the mill frame arm 14. The guides 50 are provided end rings 51 and 52 secured to the guides 50. Hydraulic capsules 53 and 54 are defined between end rings 51 and 52 and the bearing blocks 40 and 41 respectively and are sealed at either side by O-ring seals 55, 56 and 57, 58 as shown in FIG. 3. Hydraulic fluid is supplied under pressure to the capsules 53 and 54 by ports (not shown) and thus the bearing blocks 40 and 41 may be urged and moved axially towards one another to preload the entire bearing assembly 19, and moreover the whole bearing assembly 19 together with the shaft 17 may be moved axially in one direction or the other while maintaining the preload, such movement and preload being governed by the supply of fluid to the capsules 53 and 54 by means of hydraulic valves in a fluid supply system.

Referring now to FIGS. 4 and 5 there is shown a suitable fluid supply and control system. In FIG. 4, a source 60 of fluid under pressure is connected by cutoff valves to supply lines 61 and 62. Line 61 supplies capsules 53 and line 62 supplies capsules 54, the capsules being shown schematically in FIG. 4. A pressure balance control 63 having a coarse adjustment control and a fine adjustment control isolates lines 61 and 62 and is adjustable to cause an increase or decrease of pressure in line 61 balanced by a related decrease or increase respectively of pressure in line 62.

The balance control is shown in more detail in FIG. 5. A relatively large diameter cylinder 70 contains a clearance piston 71 with a bellows 72 attached at one end to the piston and at the other end to the cylinder base. The piston is mov-

ble by rotation of a threaded control knob 73 having an internal opposing shoulder arrangement 74 trapping a collar portion 75 at the remote end of a piston rod 76 attached to the piston 71. Rotation of knob 73 in one sense moves the piston 71 downwardly in FIG. 5 and rotation of knob 73 in the opposite sense raises the piston 71. The piston 71 is guided axially by a keyway 77 extending inwardly from the cylinder wall slidably engaged by a key extending outwardly of the piston.

The space 80 between the piston 71 with its bellows 72 and the cylinder 70 communicates via port 81 with supply conduit 61, and the space 91 within the bellows 72 communicates via port 82 with supply conduit 62.

A relatively small diameter cylinder 83 is mounted base to base with cylinder 70. Cylinder 83 similarly contains a clearance piston 84 having a bellows 85, the piston 84 being movable axially by a similar threaded control arrangement to that used for piston 71. The space 86 within bellows 85 communicates with space 91 and port 82 and the space 87 in cylinder 83 outside bellows 85 communicates with space 80 and port 81. It will be seen that downward movement of piston 71 increases the pressure in line 62 and decreases that in line 61 causing the bearing and shaft 17 to move to the left in FIG. 3. Similarly upward movement of piston 72 would cause the shaft to move to the right. Moreover upward and downward movement of piston 84 would cause the shaft 17 to move to the left and right respectively though to a less extent than piston 71 for each revolution of the associated control knobs, since piston 84 is of considerably less diameter than piston 71. Cylinder 70 and piston 71 thus constitute a coarse control and cylinder 83 and piston 84 a fine control on the axial position of the work roll shaft 17. The overall pressure in balanced lines 61 and 62 determines the preloading on the shaft bearing assembly 19. Adjustment of the axial position of work roll shaft 17 permits alignment of the work rolls with one another to avoid ovality in the rolled stock and also alignment of the work roll gaps from one mill stand to another. After this adjustment and before rolling the lines 61 and 62 may be shut off adjacent their capsules 53 and 54 by valves (not shown) to enhance the stiffness of the system.

The work roll shafts 17 are each further rotatably carried adjacent the work roll end in bearings in a self-contained bearing block 100. The bearing block 100 mounts bearings in the form of a matched pair of opposed tapered roller bearings 101, 102 and 103, 104. The block 100 is sealed by end ring seals 105, 106. A spacer sleeve 107 extends axially on the shaft 17 between the inner race 32 of bearing 30 in bearing assembly 19 and the inner race 108 of tapered roller bearing 104. This sleeve secures block 100 on shaft 17.

The bearing block 100 is capable of limited movement with shaft 17 within frame arm 14 in a direction parallel to the axis of shaft 17. The bearing block is also, as seen in FIG. 2, mounted for sliding movement perpendicular to the plane including the axis of shaft 17 and the stock pass line. This vertical sliding movement is controlled and may be preloaded by hydraulic piston and cylinder devices 110 and 111 situated between the blocks 100 and their respective mill frame arms 14 and 15. The blocks may also be separated for ready access to the pass line by actuation of hydraulic piston and cylinder devices 112 and 113 between the two blocks 100. Devices 112 and 113 also serve to keep the work rolls firmly in preloaded rolling engagement with their respective support rolls 12 and 13. Devices 110 to 113 may also be used for adjusting the relative vertical position of blocks 100 according to the diameter of the work roll used, and to preserve a constant pass line.

Each bearing block 100 is also slidable to a very limited extent generally parallel to said stock pass line. A load cell 120 is disposed in a cut out 121 in each mill frame arm 14 and 15 and supports the block 100 against this movement in the direction of travel of stock through the work rolls. Springs or other shock load absorbent means may be provided on the side of blocks 100 opposite said load cells 120.

It will be appreciated that movement of each block 100 in the three generally perpendicular directions is permitted by

bearing assembly 19 which permits universal pivotal movement of the shaft about point 20.

Since the rolling load is absorbed by the support rolls 12 and 13 the load registered by the load cells together is caused by and is proportional to the tension in the stock adjacent the stand. If desired load cells may also be disposed on the opposite side of blocks 100 to provide a measure of negative stock tension. The output signals produced by the load cells may be utilized in control of the rolling process, particularly in twin or multistand mills. In particular the output signals may be utilized to control the drive speed of the rolls 10 and 11 in order to control the stock tension and desirably in order to maintain the stock tension at a desired value. It will be seen from FIG. 2 that the axes of rotation 125 and 126 of the two support rolls 12 and 13 are very slightly offset from the plane including the work roll axes. The upper support roll is offset to the right parallel to the stock pass line and the lower support roll is offset to the left to a similar extent. If the axes of rotation of the work rolls and the support rolls were to lie on a common vertical line as is conventional then if the work rolls were to move slightly to the left as seen in FIG. 2 under increasing stock tension, the roll gap between the work rolls 20 and 21 would be slightly increased as the work rolls would tend to roll outwardly and upwardly round the support rolls.

The described offset arrangement overcomes this difficulty in that as the work rolls move to the left, or even to the right, as seen in FIG. 2, they remain in contact with the support rolls because as for instance the upper work roll 20 rides down the upper support roll, the lower work roll rides up the lower support roll by the same amount for a given sideways movement and vice versa. Thus it can be seen that the roll support is maintained at a constant roll gap determined by the arms 14 and 15.

A further advantage of the described embodiment is that there is consistent overall mill stiffness, leading to a constant transfer function for the stock tension control system and any other mill control systems. The stiffness is consistent because only one mating surface—the interface between each work roll 10 and 11 and its support roll 12 and 13—is disturbed during work roll changing or roll redressing. Moreover all surfaces in the rolling load pass are prestressed, including the support roll bearings, thus ensuring that rolling takes place on the linear portion of the stiffness curve.

Further advantages and applications and features of the described mill stand will be found in our two related copending patent applications referred to hereinbefore.

We claim:

1. A rolling mill stand comprising a frame, two work rolls, two work roll drive shafts rotatably carried in said frame, each shaft having a driven end and a free end, means securing each work roll axially to the free end of its associated drive shaft, at least one of said shafts having means associated therewith defining an axis which extends perpendicular to and is displaced from the stock pass line between said work rolls, said axis also intersecting the associated work roll drive shaft axis at an intersection point fixed in position relative to said one shaft, said one shaft being movable to a limited extent about said defined axis through said intersection point, whereby the work roll secured to said movable shaft is also movable to a limited extent about said defined axis and cannot translate bodily in the direction of the stock pass line without moving about said defined axis, and wherein a load sensing device is provided acting between said movable shaft and said frame, said device providing in use a signal embodying a measure of the tension in the stock adjacent said mill stand.

2. A rolling mill stand according to claim 1 wherein said movable shaft is rotatable in bearings within a self-contained bearing block slidable in said frame generally parallel to said stock pass line, said load sensing device being disposed between said self-contained bearing block and said frame.

3. A rolling mill stand according to claim 2 wherein said self-contained bearing block is also slidable in said frame in a line generally parallel to said first mentioned axis, and means

for adjusting the position of said self-contained bearing block in said line.

4. A mill stand according to claim 1 wherein each said work roll drive shaft has means associated therewith defining an axis common to said shafts which extends perpendicular to and is displaced from the stock pass line between said work rolls, said common axis also intersecting the work roll drive shaft axes at respective intersection points fixed in position relative to their respective shafts, each said shaft being movable to a limited extent about said defined common axis through said intersection points, whereby each work roll is also movable to a limited extent about said defined common axis and cannot translate bodily in the direction of the stock pass line without moving about said common defined axis, and wherein a load sensing device is provided acting between each said movable shaft and said frame, said devices each providing in use a signal embodying a measure of the tension in the stock adjacent said mill stand.

5. A rolling mill stand according to claim 4 wherein the work rolls are backed up by support rolls, the axis of rotation of one said support roll being slightly offset from the plane including the work roll axes in a direction parallel to the stock pass line, and the axis of rotation of the other said support roll being slightly offset from said plane in the direction opposite to said first mentioned direction.

6. A rolling mill stand according to claim 4 including means responsive to each said load sensing device signal to control the speed of rotation of the work rolls so as to tend to maintain the stock tension at a desired value.

7. A rolling mill stand according to claim 4 wherein both said movable shafts are movable to a limited extent in any direction about said respective defined intersection points, wherein support rolls are provided backing up the work rolls, and wherein force-applying means act between said shafts to tend to force said shafts angularly apart about respective second axes extending through the respective intersection points parallel to the stock pass line, whereby to urge the work rolls into preloaded engagement with their respective support rolls.

8. A mill stand according to claim 1 wherein said movable shaft is movable to a limited extent in any direction about said defined intersection point.

9. A rolling mill stand according to claim 8 including means acting on said movable shaft to controllably adjust the angular position of said movable shaft about a second axis intersecting said first axis at said intersection point and extending parallel to said stock pass line.

10. A rolling mill stand according to claim 8 wherein said movable shaft is rotatably mounted in preloaded bearing means.

11. A rolling mill stand according to claim 8 wherein said movable shaft is rotatably mounted in bearing means, said bearing means defining said intersection point, and said bearing means locating said movable shaft both axially and radially while permitting pivotable movement to a limited extent in any direction about said intersection point.

12. A rolling mill stand according to claim 8 wherein said movable shaft is rotatably mounted in self-aligning bearing means.

13. A rolling mill stand according to claim 12 wherein said self-aligning bearing means has an outer bearing block slidable to a limited extent generally axially with said movable shaft, said block being slidable in a bearing block guide secured to said frame.

14. A rolling mill stand according to claim 13 including hydraulic capsules defined between said outer bearing block and said bearing block guide adjacent each end of said outer bearing block, and means for controllably supplying fluid under pressure to said capsules, whereby the axial position of said outer bearing block relative to said guide is controllably adjustable.

15. A rolling mill stand according to claim 14 wherein said means for controllably supplying fluid under pressure to said capsules is adapted to maintain fluid under pressure in said capsules adjacent each end of the bearing block, whereby to preload the self-aligning bearing means.

16. A rolling mill stand according to claim 8 wherein said movable shaft is rotatably mounted in bearing means including a spherical roller bearing, the inner bearing face of the outer race of said spherical roller bearing being part-spherical about said point, and two opposed angular contact ball bearing assemblies disposed axially on the shaft one at each side of said spherical roller bearing, and two self-aligning bearing means disposed adjacent the two angular contact ball bearing assemblies at the side thereof remote from the spherical roller bearing and having bearing surfaces lying in a common sphere centered on said point, the outer bearing block of said self-aligning bearing means being slidable to a limited extent generally axially with said shaft, said outer bearing block being slidable in a bearing block guide secured to said frame.

17. A mill stand according to claim 1 wherein said movable shaft is rotatable in bearing means mounted in said frame, said bearing means defining said intersection point, and wherein said load sensing device is disposed intermediate the stock pass line and said intersection point.

18. A roll mill stand according to claim 1 including means acting between said movable shaft and said frame to controllably adjust the axial position of said movable shaft relative to said frame.

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