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Dowsing et al.

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[54] **SLAB ROLLING**

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[73] Assignee: **Davy and United Engineering Co. Ltd., Sheffield, England**

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[52] **U.S. Cl.**.....**72/21**, 72/240

[51] **Int. Cl.**.....**B21b 37/14**

[58] **Field of Search**.....72/8–12, 19, 21, 72/7

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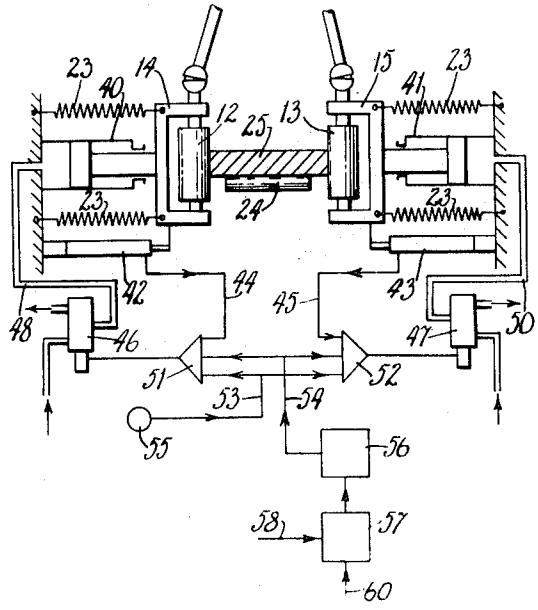
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[57] **ABSTRACT**

When rolling a steel slab along its edges to reduce its width the head end of the slab may experience a larger percentage reduction than the mid portions of the slab. A similar situation, but to a less marked extent may occur at the tail end of the slab. To avoid this disadvantage workpieces are rolled in a vertical mill stand and the roll gap of the mill stand is automatically controlled during rolling. In the combination of a vertical mill stand and a horizontal mill stand in which slabs are successively edge and flat rolled an automatic control system is employed to control means for adjusting the roll gap of the vertical stands during the rolling of at least a terminal length of the slab adjacent an end so as to produce a width profile such that after subsequent horizontal rolling the width of the terminal length is not less than the width of the remainder of the slab.

3 Claims, 2 Drawing Figures



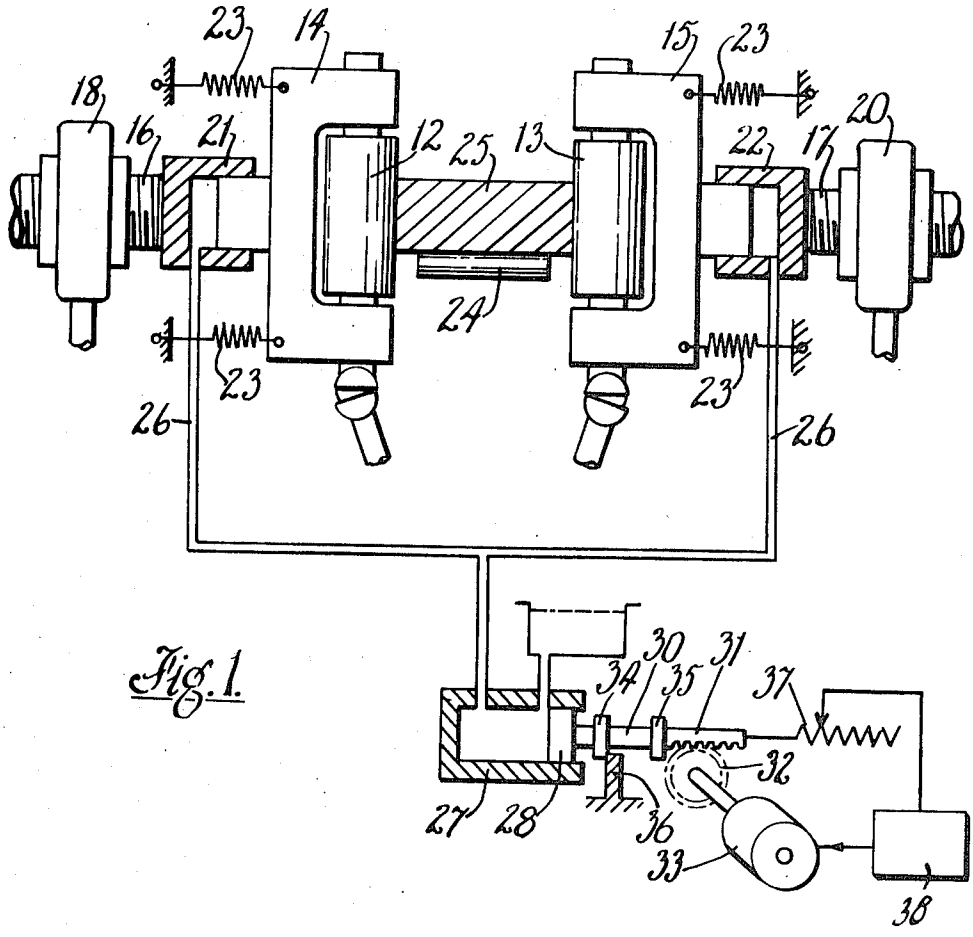

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Fig. 1.

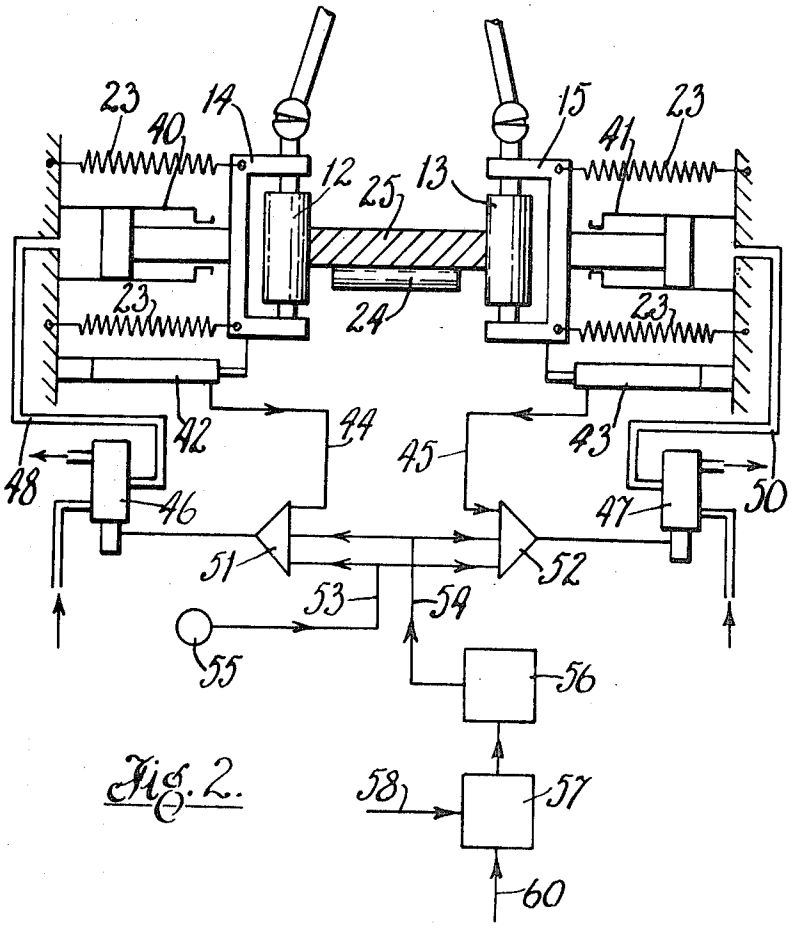

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Fig. 2.

SLAB ROLLING

This invention relates to the rolling of metal workpieces and is particularly concerned with the preliminary edge rolling of a steel slab to reduce its width.

The reductions taken by the edging stands of hot strip mills have been in the past relatively small, larger reductions having been found to produce bad edge shape in the eventual strip, after horizontal or flat rolling. As a consequence, slabs are normally stocked in the range of widths, having increments of one half inch widths, to accommodate the variations in strip widths required. The cost of providing a stock of slabs having so many different widths is substantial.

We have discovered that if a relatively large reduction is taken in a vertical edger mill, there is a danger that, although the roll gap of the mill may be held nominally constant, the head end of the slab may experience a larger percentage reduction than the mid-portions of the slab. Although the increased reduction may be effective for less than a foot length of the slab, the result is the production of up to 100 feet of strip with a width smaller than that required. This narrower strip length must be discarded, or the remainder of the strip trimmed to the smaller widths. A similar situation, but to a less marked extent, may occur at the tail end of the slab.

We believe that as the head end of the slab passes through the edger mill, there is relatively little resistance to metal movement in the forward direction and material is drawn forward between the rolls at roll gap width. As the slab progresses through the mill, initially the width of the part already drawn through the rolls is reduced by shearing forces communicated from the material then between the rolls. The effect decreases as the slab progresses through the roll gap, and the resistance to deformation increases until, after about eight inches from the head end, the displacement of metal caused by the rolling operation appears largely as an increase in the slab thickness. The outcome is firstly a width taper from the head end over about the first eight inches, and secondly the production of a dog-bone section in the slab where the displaced metal is unable to move lengthwise. When the slab is subsequently rolled in a horizontal mill, the dog-bone section is rolled out, increasing the width of the slab again; the head end however is free of the dog-bone section and does not therefore experience the same width enlargement. Consequently both the angle of the taper and the extent of the taper are increased.

In the horizontal rolling stands, a flare of the head end is produced naturally. This flare offsets to some extent the taper produced in the vertical mill stand. However, the length of material over which the flare occurs remains roughly constant while the workpiece is elongated as it is reduced in thickness. The result is that the width at the extreme head end of a finished strip may be approximately the same as that at mid-length, but there is a length of up to 100 feet of strip just inside the head end which is narrower than either.

We have found that it is possible to prevent or reduce the production of off-widths slab by initially setting the rolls to a separation greater than that required for the main body of the slab and progressively decreasing the roll separation over the first part of the slab length. The variation in separation is chosen so as to compensate for the width variations mentioned above, in order to achieve after horizontal slab rolling substantially constant width or a head end with a width greater than that of the main body of the slab, since the strip head end may then be trimmed to width at little expense. The same procedure may be followed in reverse at the tail end.

Accordingly, one aspect of the present invention resides in a method of rolling workpieces in a vertical mill stand in which the roll gap of the mill stand is automatically controlled during rolling.

A second aspect of the invention resides in a method of rolling a metal slab in which the slab is edge-rolled in a vertical mill stand and subsequently is flat rolled in a horizontal mill stand, and in which the roll gap of the vertical mill stand is automatically varied during rolling of a terminal length of the slab adjacent an end, to obtain a width profile such that, on subsequent flat rolling, the widths of the corresponding terminal lengths is not materially less than the widths of the remainder of the slab. In particular, at the head end of the slab, the roll gap may be progressively reduced during the first part of the slab length.

Another aspect of the invention lies in the combination of a vertical rolling mill stand and a horizontal mill stand in which slabs are successively edge-and flat-rolled, means for adjusting the roll gap of the vertical stand, and an automatic control system for controlling the adjusting means during the rolling of at least a terminal length of the slab adjacent an end so as to produce a width profile such that, after subsequent rolling in the horizontal stand, the width of the corresponding terminal length is not materially less than the width of the remainder of the stand.

By controlling the roll gap on the vertical mill stand by the invention, it is possible to take greater reductions in that stand than has previously been possible without producing unacceptable amounts of scrap in the rolled strip. As a consequence, a more limited number of slab widths need be stored; thus, the stored slab width increment may be increased from the half inch previously mentioned to 2 inches, the required variation in strip widths being obtained by selection of the amount of reduction taken from the slabs. Reducing the number of stock width slabs results in considerable saving in cost.

Where, for example, a net reduction of slab widths of 1½ inches is required from a standard slab width, in order to achieve a required width in the final strip, the vertical rolls may have to be set to reduce the slab widths by 3 inches or 3½ inches, to allow additionally for the width regained by rolling down the dog-bone section in the next horizontal rolling pass. In such a case, the overall taper produced at the head end might be about two inches extending over 12 to 20 inches of the slab length. To prevent the occurrence of this taper, the rolls of the vertical mill are initially set at two inches greater than that to achieve the reduction of 3 to 3½ inches, and the roll gap progressively decreased over the first twelve to twenty inches of the slab length. If the rolling speed is three feet a second, this reduction in roll gap must be made in from 0.3 to 0.6 seconds. It must also be carried out against the rolling load which may be 300 tons.

As a rapid acting mechanism is required in order to adjust the roll gap quickly, the normal screw devices for setting the roll gap of vertical rolls must be replaced by rapid-acting screw adjusting mechanisms or, preferably, by replacing or supplementing the normal screw devices by a hydraulic actuator. However, other mechanism for setting and adjusting the roll gap, such as wedges, and electric thrustors, may be employed in place of the screws.

The invention will be more readily understood by way of example from the following description of a vertical rolling mill stand and controls therefor, reference being made to the accompanying drawings, in which

FIGS. 1 and 2 illustrate alternative forms of vertical mill stand with different forms of control.

Referring to FIG. 1, the vertical mill stand is illustrated schematically by a pair of vertical rolls 12, 13 supported in their respective roll carriages 14, 15. The positions of the vertical rolls 12, 13 are set by screws 16, 17, which are threaded into nuts 18, 20 which are supported by the mill frame and which are driven by an electric motor (not shown).

Interposed between the screws 16, 17 and the roll carriages 14, 15 are two hydraulic short-stroke capsules 21, 22. Springs 23 act on the roll carriages 14, 15 and bias them in directions tending to open the roll gap. These springs take up back-lash in the screws 16, 17 and provide forces to return the pistons of the capsules 21, 22 when the pressure of the hydraulic supply is withdrawn; the springs 23 may be replaced by pull-back cylinders providing a small constant force sufficient to overcome friction.

A roller table, exemplified by the roller 24 is arranged to lead workpieces (the slab 25), into and out of the vertical mill.

The screws 16, 17 are initially set to a value equal to the setting required to achieve the desired reduction of the slab widths, plus the amount of width taper that would be achieved, if the roll gap was held fixed throughout the length of the slab. Thus, in the example previously given, the screws 16, 17 are set to give a roll gap two inches greater than that required for the desired reduction. During the rolling of the first 12 to 20 inches of the slab length, the roll gap is decreased by operation of the cylinders 21, 22, so that at the end of that length, the roll gap is that required for the desired reduction. The operation of the capsules 21, 22 is controlled by the control system shown in the lower half of FIG. 1.

The control system is arranged to cause the roll gap between rolls 12, 13 to be decreased at a constant rate. The two capsules 21, 22 are connected through lines 26 to a cylinder 27, having a piston 28. The piston 28 is connected by its rod 30 to a rack 31, which meshes with a pinion 32 driven by a motor 33. As the slab 25 approaches the edging rolls, its leading edge is detected by a photocell (not shown) and, after a delay appropriate to the distance of the photocell from the roll bite and the speed of the roller table 24, the adjusting motor is switched on. The motor drives the rack 31 from right to left as viewed in FIG. 1 and liquid is forced out of the cylinder 27 through the lines 26 and into the capsules 21, 22 to cause a decrease in the roll gap. The cross-sectional area of the cylinder 27 is less than the sum of the areas of the capsules 21, 22 so as to effect a force amplification.

The piston rod 30 carries collars 34, 35 which cooperate with a fixed stop 36 to set the extreme limits of movement of the piston 28 and therefore of the capsules 21, 22. The collars 34, 35 are set at a separation which, taking into account the force amplification, achieves the required reduction in roll gap during the rolling of the head end of the slab. Similarly, the speed of the motor 33 is set so that the piston 28 is driven from one extreme limit to the other in the time for the head of the slab to enter the rolls by twelve to twenty inches. Preferably, the fixed stop 36 takes the form of a limit switch which is actuated by the collars 34, 35 to de-energize the motor 33 at the ends of the travel.

Instead of having the motor 33 rotating at constant speed, its speed may be controlled in accordance with the varying value of the roll gap according to a preselected pattern. For this purpose, a transducer, shown as a potentiometer 37 may be coupled to the rack 31 and its signal employed to control the motor speed control circuit 38 of motor 33.

Again, the motor 33 may be controlled by a closed loop system in accordance with the position of the slab 25 in relation to the roll gap. For this purpose, a slab position transducer, such as a scanning type photocell located above the roll gap, is provided to give a signal representing the position of the head of the slab as the head approaches and enters the roll gap. The resulting position signal is compared with the signal from the rack transducer 37 and the motor 33 controlled accordingly, in order that, at each position of the slab 25 within the roll gap, the roll gap has a given preselected magnitude.

It will be appreciated that, although two capsules 21, 22 have been illustrated and described, it is possible to employ a single capsule, which in that case must have a larger travel than either of the two illustrated. It will also be understood that, although the operation has been described in relation to the reduction in roll gap at the entry of the head end of the slab, a similar operation may be effected as the tail end passes through the roll gap, the roll gap being increased over the last terminal length of the slab; the control system is as illustrated and operates in reverse to the procedure described.

In FIG. 2 the screws 16, 17 of FIG. 1 are dispensed with and the function of the screws 16, 17 and capsules 21, 22 is performed by piston and cylinder assemblies 40, 41 arranged between the mill frame and the carriages 14, 15.

Each of the assemblies 40, 41 has associated with it a position transducer 42, 43 giving, on lines 44, 45 signals representing the positions of the roll carriages 14, 15 in relation to the mill housing. The cylinder of each of the assemblies 40, 41 is supplied with liquid under pressure through respective pilot valves 46, 47 and lines 48, 50. Each pilot valve is controlled by the output of one of two amplifiers 51, 52 which receive position signals from the respective transducers 44, 45 respectively and also receives signals representing the required roll gap setting. In the amplifiers, the required setting is compared with the actual setting as represented by the signals on lines 44, 45 and the pilot valves 46, 47 controlled to maintain the two in equality.

The datum signals representing the required roll gap setting are derived on lines 53, 54, which are connected in parallel to the amplifiers 51, 52, and which are con-

nected respectively to a manually controlled device **55** for setting the gap required during the rolling of the mid portions of the slab, and from a generator **56** which gives a signal which varies at the speed of the required change in roll gap during the rolling of the slab end. The generator **56** is controlled by an initiating device **57** which receives signals on line **58** from a photocell detecting the approach of the slab, and a line **60** from a timing mechanism such that the device **57** initiates the generator **56** as the head end enters the roll gap. Generator **56** is a potentiometer or like device which generates a ramp voltage which decreases over the time taken by the first 12 to 20 inches of the slab to pass through the roll gap and by an amount needed to reduce the roll gap from the initial value to the value set by device **55**. Alternatively, a closed loop control system may be employed, the signal on line **60** being derived from a slab position transducer, the generator **56** then giving a signal to amplifiers **51, 52**, which signal varies in a prescribed pattern with the position of the slab within the roll gap.

Whatever control system is employed, the roll gap is decreased over the head end of the slab to compensate for the taper in the head end that would otherwise be produced during the vertical rolling and subsequent horizontal rolling. As a result, the strip rolled from the slab does not have an appreciably smaller width at the head end than in the mid length and no trimming of the mid length is required. The same operation occurs at the tail end, again with the aim of achieving a strip of substantially constant width along its length.

We claim:

1. A method of rolling a metal slab which comprises the steps of

first edge rolling said slab in a vertical mill stand while progressively decreasing the roll gap of said vertical mill stand as a first portion of said slab passes therethrough to impart a selected width profile to said first portion, maintaining said roll gap substantially constant during the edge rolling of at least the major part of the remainder of said slab, subsequently flat rolling said slab in a horizontal mill stand, and so selecting said width profile that after said subsequent horizontal flat rolling the width of said first portion of said slab is at least as great as that of said major part of said slab.

2. A method as claimed in claim **1** which also comprises the step of increasing said rolling gap as the last portion of said slab passes through said vertical mill stand so that after said subsequent horizontal flat rolling the width of said last portion of said slab is at least as great as that of said major part.

3. A method of rolling a metal slab as claimed in claim **1** in which said roll gap is decreased at constant speed.

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