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A. W. SMITH, JR
SPEED CONTROL SYSTEM FOR EDGER AND OTHER
ROLLS IN A REDUCTION ROLLING MILL
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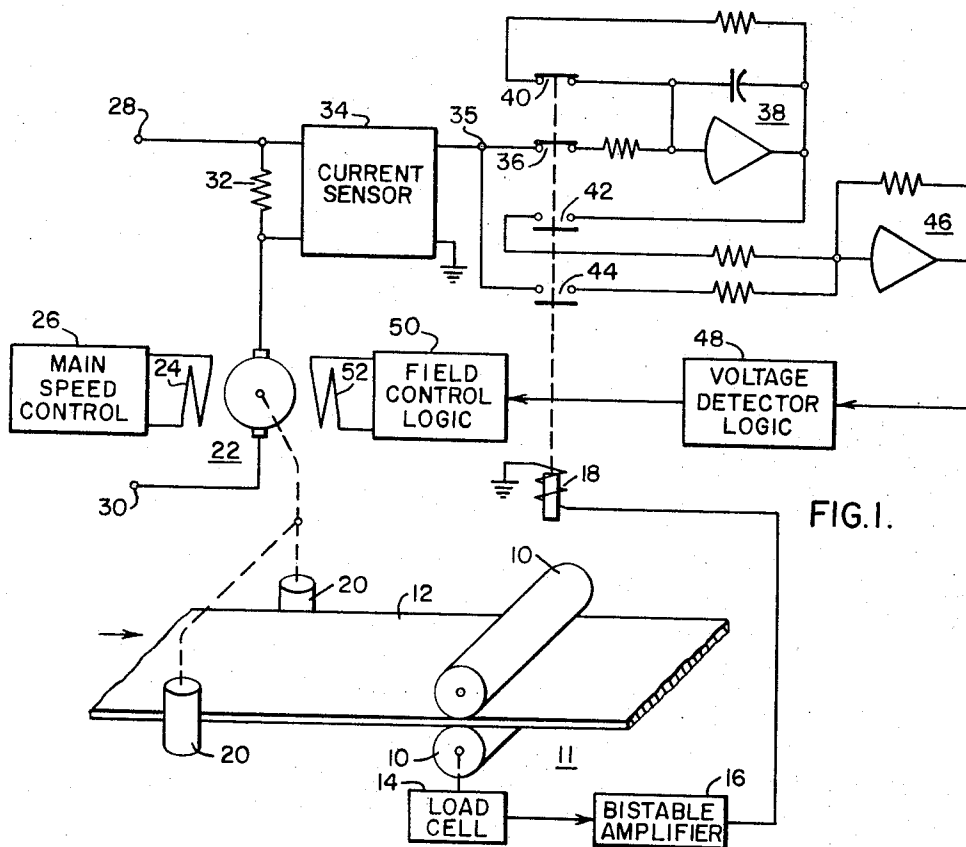


FIG.1.

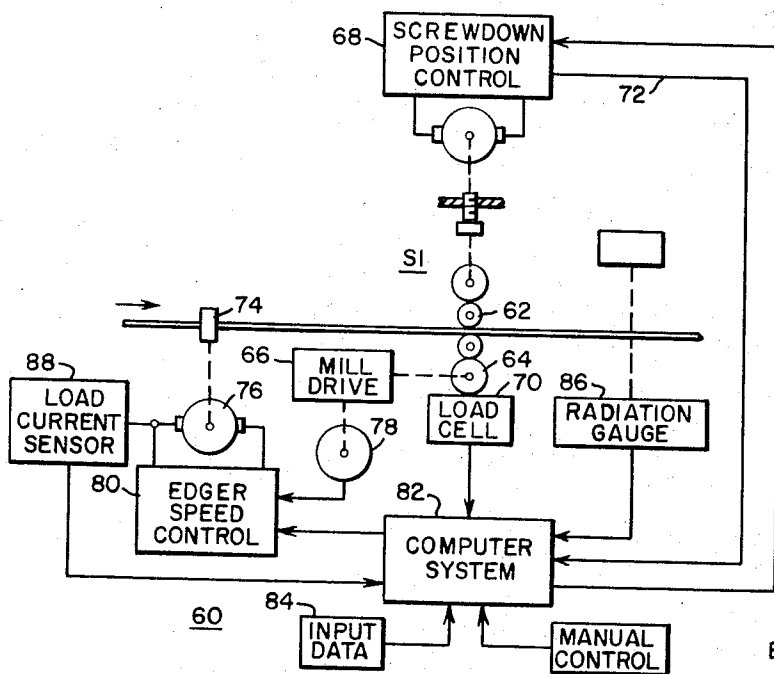


FIG. 2.

INVENTOR
Andrew W. Smith, Jr.
BY *E. F. Passensky*

ATTORNEY

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SPEED CONTROL SYSTEM FOR EDGER AND OTHER ROLLS IN A REDUCTION ROLLING MILL

Andrew W. Smith, Jr., Pittsburgh, Pa., assignor to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

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5 Claims. (Cl. 72-8)

The present invention relates to reduction rolling mills and more particularly to speed control systems for edger and other rolls in steel rolling mills.

Generally, edger rolls are normally vertically disposed to provide width control of the material rolled in a reduction mill. In steel mills, edger rolls can ordinarily be effectively used for the thicker forms of in-process steel such as slabs or billets. When the steel thickness is less than about one inch, edger rolls become less effective or become altogether ineffective because of side-to-side buckling of the workpiece. In controlling the width of slabs or billets, edger rolls are usually located in front of the horizontal roll stand in a reversing mill or in front of preselected horizontal roll stands in a multistand mill. The edger rolls are positioned in relation to the workpiece to reduce the workpiece width to a predetermined value. The proper operation further depends on the relative speed of the edger rolls and the rolls at the next successive horizontal roll stand. Overspeed of the edger may result in the buckling of the piece between the edger and the horizontal roll stand and underspeed may result in necking of the piece. Improper speed matching may also cause excessive slippage of the rolls. During the workpiece pass, it is therefore desirable that the speed of the edger rolls and the next successive horizontal rolls be matched for proper edger control. By roll speed matching, it is meant to refer to a condition in which the edger rolls substantially neither drive nor are driven by the horizontal rolls through the medium of the passing workpiece. Since various drafts at the horizontal rolls can result in various workpiece pass speeds at the edger rolls, the edger and horizontal roll peripheral speeds need not be the same when speed matching is realized but depend on the draft in the horizontal mill rolls.

Prior to a workpiece pass, the edger roll speed can be preset by an operator or a computer on the basis of information as to the reduction to be made by the horizontal rolls, the unloaded speed of the horizontal rolls and the edger and horizontal roll diameters. However, during the subsequent workpiece pass, precise roll speed matching is rarely realized because of the wide variability of rolling parameters. Manual speed adjustment is theoretically possible, but it is subject to imprecision and further is impractical in many applications such as in billet reduction where a single pass can occur in less than 5 second.

Similar problems of speed matching exist where tandem horizontal stands are employed. The first roll set may be driven by a predetermined power drive and the second roll set may be driven by a comparatively higher power drive so that roll speed matching is required for reasons similar to those described in connection with the speed control of edger rolls. In the alternative, the first roll set may be driven by a variable speed DC motor and the second roll set may be driven by a synchronous motor so as to provide another similar case where roll speed matching is required.

In accordance with the broad principles of the present invention, matched speed of tandem motor driven roll sets, such as an edger roll set and a horizontal roll set, is obtained by a speed control system which includes means

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for sensing the first motor loading after workpiece entry to the first roll set and before workpiece entry to the second roll set. The sensing means also detects the first motor loading after workpiece entry to the second roll set. Feedback error sensing means promptly adjusts the first motor speed to match the first and second roll speeds.

It is, therefore, an object of the invention to provide a novel system for controlling the speed of edger or other rolls so as to provide improved and more accurate rolling in a reduction rolling mill.

Another object of the invention is to provide a novel control system which efficiently and automatically matches edger roll and horizontal roll speeds or tandem horizontal roll speeds during a workpiece pass in a reduction rolling mill.

These and other objects of the invention will become more apparent upon consideration of the following detailed description along with the attached drawings, in which:

FIGURE 1 schematically shows an embodiment of the invention in which analog circuitry is employed to produce edger and horizontal roll speed matching at a single horizontal roll stand location; and

FIG. 2 schematically shows an embodiment of the invention in which a computer is operated to produce edger and horizontal roll speed matching at the various stand locations.

More specifically, there is shown in FIG. 1 a set of horizontal work rolls 10 which are provided in a roll stand 11 to reduce the gauge of a workpiece 12 in the form of a steel slab or billet or any other suitable form of plastically deformable material. Suitable backup rolls (not shown) and a suitable screw down position control (not shown) are provided to produce force on the horizontal work rolls 10 and control the work roll opening in a conventional manner. A suitable motor drive (not shown) is operated by a suitable speed control (not shown) to drive the work rolls 10 as is well known in the art.

The workpiece draft made by the horizontal rolls 10 is set by the mill operator or by a process computer, and gauge control is effected by the screw down position control on the basis of the well known roll force principle either through analog feedback circuitry or through feedback circuitry including a process computer. The roll force signal is generated by a commercially available load cell 14, and the load cell output is additionally connected to a roll force bistable amplifier detector 16 which operates a roll force detector relay 18 when the workpiece 12 first enters between the horizontal work rolls 10.

A set of edger rolls 20 of ordinary design are vertically disposed in spaced relation to the horizontal work rolls 10 and on the entry side thereof so as to produce edge drafting and workpiece width control. If the stand 11 is operated as a reversing stand, another set of edger rolls (not shown) can be placed on the opposite side of the rolls 10. A motor drive 22 jointly operates the edger rolls 20, or separate motor drives can be provided for the respective edger rolls 20 if desired. The edger drive motor 22 has relatively low power as compared to the work roll drive. It is preferably a variable speed DC motor provided with a main field winding 24 which is energized by a main speed control unit 26 to provide general speed control. Motor armature terminals 28 and 30 are energized from a suitable power supply (not shown) and a resistor 32 is included in the armature circuit so as to provide a basis for sensing the edger motor loading and in particular the edger motor armature current. A current sensor 34, in the form of a suitable commercially available device such as a 10 kilocycle magnetic amplifier current sensing device, is connected across the armature resistor 32 to pro-

duce a voltage at output terminal 35 representative of the edger motor armature current.

In operation, the edger rolls 20 are positioned along a reference line lateral to the longitudinal direction of the workpiece 12 so as to produce the desired edge draft and the workpiece 12 is transported between the edger rolls 20. The edger motor speed can be preset for rough matching of the edger and horizontal roll speeds during the workpiece pass. Prior to workpiece entry to the horizontal rolls 10, a normally closed contact 36 of the roll force detector relay 18 applies voltage to an integrator 38 of suitable design, such as a commercially available transistor amplifier integrator. Normally closed contact 40 of the relay 18 allows the integrator 38 to produce an output voltage which follows the edger motor armature current during the period after workpiece entry to the edger rolls 20 and before workpiece entry to the horizontal rolls 10. The integrator output voltage is indicative of the edger motor loading required for the predetermined edge draft, and it is blocked from producing further circuit functioning by a normally open contact 42 of the relay 18.

When the workpiece 12 enters the horizontal rolls 10, the roll force detector 16 operates the relay 18 and the contacts 36 and 40 are opened to hold the integrator output voltage at the voltage level then existing. The contact 40 recloses to reset the integrator after the workpiece pass. The held integrator output voltage substantially represents the edger motor armature current existing after workpiece entry to the edger rolls 20 and before workpiece entry to the horizontal rolls 10, i.e., the required edge draft loading.

When the relay 18 is operated, a normally open contact 44 thereof is also closed and the output voltage from the edger current sensor 34 and the output voltage from the integrator 38 are both applied to an error detector amplifier 46, such as a transistor differential amplifier. The output voltage from the current sensor 34 now represents the edger motor armature current after workpiece entry to the horizontal rolls 10.

Any error voltage represents a deviation in edger motor loading, i.e. the edger motor 22 is either overloaded and pushes the workpiece through the horizontal rolls or it is underloaded and is pulled by the horizontal rolls. The error voltage is applied to suitable voltage detector logic 48 which operates field control logic 50 so as to provide feedback control of the magnitude of voltage applied to an edger motor draft compensation field winding 52 and thereby control the edger motor speed in accordance with the motor speed characteristics. The edger motor field winding 52 is designated as providing draft compensation because it effects edger and horizontal roll speed matching under various draft conditions set for the horizontal rolls 10.

As an example, the field control logic 50 can simply be a tapped resistor (not shown) connected to a DC voltage supply with the various tap points connected through contacts (not shown) associated with respective relays (not shown) operatively controlled in the voltage detector logic 48. The error voltage generated by the error detector 46 thus operates through the draft compensation field winding 52 to retain the proper edger motor loading by matching the edger roll speed with the horizontal roll speed after horizontal roll force detection is made. The error voltage goes to zero when speed matching is realized. Any subsequent change in horizontal roll speed is matched by changes in edger roll speed since the error detector output voltage follows changes in the edger motor armature current. The invention achieves similar results if horizontal rolls are employed in place of the vertical edger rolls 20 and the motor drive for the first horizontal rolls is small compared to the motor drive for the second horizontal rolls 10 or the first motor drive is a variable speed DC motor and the second motor drive is a synchronous motor.

In FIG. 2, there is shown another embodiment of the

invention in the form of a mill 60 which includes a horizontal stand S1 having horizontal work rolls 62 and backup rolls 64 driven by a mill drive 66 under suitable speed control. A screw down position control 68 is also operated at the stand S1 to control the force applied to the work rolls 62 and thereby to control the draft made at the stand S1. A roll force signal generated by a load cell 70 and a screw down position signal as indicated by the reference character 72 are made available for gauge control and other purposes.

Edger rolls 74 are located in front of the horizontal roll stand S1 and are operated by an edger drive motor 76 having relatively low power compared to the drive 66. A pilot generator 78 is connected to an edger speed control 80 to provide a general correlation between the edger motor speed and the mill drive speed. For example, a separate edger motor field winding (not shown), often called a pattern field winding, can be energized by the pilot generator 78 in effecting the general speed correlation.

A suitably designed digital computer system 82 includes suitable input and output analog-to-digital and digital-to-analog converters, and the system 82 is suitably programmed and is supplied with command data from an input data device 84 to control the overall operation of the mill 60. During the rolling process, operating variables including roll force, screw position, delivery thickness from a radiation gauge 86, and if desired other variables (not indicated) such as workpiece temperature signals and speed of the mill drive are transmitted to the computer system 82 to provide the data necessary for maintaining ongoing feedback control of the rolling process. In effecting the mill control, computer outputs control the screw down position control 68 at the stand S1 and if desired the mill drive 66 (not indicated).

In accordance with the principles of the present invention, the computer 82 also provides feedback control of the edger speed control 80 so as to match the speed of the edger rolls 74 with the speed of the horizontal work rolls 62 in the stand S1. Thus, an armature load current sensor 88, such as that described in connection with FIG. 1, is connected from the edger motor 76 to the computer 82. The computer 82 is programmed to memorize the armature current in the edger motor 76 before workpiece entry to the horizontal rolls 62, to detect the initial roll force signal at the stand S1, to record the armature current in the edger motor 76 after workpiece entry to the horizontal rolls 62, and to compare the pre-entry and post-entry armature currents for the edger motor 76. A resultant error signal operates the edger speed control 80 as the workpiece is transported through the stand S1 so as to match the edger and horizontal roll speeds. To produce speed matching, a draft compensation field winding can be provided for the edger motor 76 in the edger speed control 80 and operate as described in connection with FIG. 1.

In sensing the pre-entry and post-entry armature current for the edger motor 76, it is preferable that a sampling technique be employed so that transient edger motor armature currents can be ignored during initial entry of the workpiece between the horizontal rolls 62. For example, time successive edger armature current signals A1, A2, A3 and A4 may be generated for the edger motor 76 and A4 may represent post-entry edger armature current. A3 may be generated during the transient period of workpiece entry into the horizontal rolls 62. A2 may represent the final pre-entry edger armature current figure and it is the value which is stored for comparison with the post-entry value. A3 is ignored in the comparison process.

To effect the sampling technique, the computer is suitably designed and programmed to store the time successive edger motor armature currents for scanning at the appropriate time. The first edger motor current sample which indicates a current value change is rejected as a

transient and the previous sample is used for comparison with the next and successive edger motor current samples. As in the case of FIG. 1, the feedback control of FIG. 2 has special utility with certain rolls other than edger rolls.

The described embodiments of the invention result in improved rolling as a consequence of precise matching of edger and horizontal roll speeds or tandem horizontal roll speeds through feedback control. The embodiment in FIG. 1 employs principally analog circuitry to achieve speed matching on the basis of the comparison of edger armature current values at predetermined operating time points. In FIG. 2, analog and digital computer circuitry is employed to effect the feedback control of tandem roll set speed matching.

The foregoing description has been presented only to illustrate the principles of the invention. Accordingly, it is desired that the invention be not limited by the embodiments described, but, rather, that it be accorded an interpretation consistent with the scope and spirit of its broad principles.

What is claimed is:

1. A control system for a reduction rolling mill having a first set of rolls driven by a first variable speed motor and a second set of rolls driven by a second motor, said system comprising means for sensing the first motor loading after workpiece transport between the first rolls and prior to workpiece entry to the second rolls, means for sensing the first motor loading after workpiece entry to the second rolls, and means responsive to both of said sensing means for adjusting the first motor drive speed to match the first roll speed with the second roll speed after workpiece entry to the second rolls.

2. A control system for a reduction rolling mill having a first set of rolls driven by a first variable speed motor and a second set of rolls driven by a second motor, said system comprising means for sensing the first motor armature current after workpiece transport between the first rolls and prior to workpiece entry to the second rolls, means for sensing the first motor armature current after workpiece entry to the second rolls, and means responsive to both of said sensing means for adjusting the first motor drive speed to match the first roll speed with the second roll speed after workpiece entry to the second rolls.

3. A control system for a reduction rolling mill having a first set of rolls driven by a first variable speed motor and a second set of rolls driven by a second motor, said system comprising means for sensing the first motor armature current, means for storing the first motor armature current existing after workpiece transport between the first rolls and prior to workpiece entry to the second rolls, an armature current error detector, means respon-

sive to roll force of the second rolls after workpiece entry to the second rolls for gating the output from said sensing means and said storing means to said error detector, and means responsive to said error detector for adjusting the first motor drive speed to match the first roll speed with the second roll speed after workpiece entry to the second rolls.

4. A control system for a reduction rolling mill having a set of edger rolls driven by a variable speed motor and a set of horizontal rolls driven by a motor having high power compared to the edger motor, said system comprising means for sensing the loading of the edger motor drive after workpiece transport between the edger rolls and prior to workpiece entry to the horizontal rolls, means for detecting workpiece entry to the horizontal rolls, means for sensing the loading of the edger motor drive after workpiece entry to the horizontal rolls is detected, and means associated with the edger motor drive and responsive to both of said sensing means for adjusting the edger motor drive speed to match the edger roll speed with the horizontal roll speed after workpiece entry to the horizontal rolls.

5. A control system for a reduction rolling mill having a first set of rolls driven by a first variable speed motor and a second set of rolls driven by a second motor, said system comprising means for sensing the loading of the first motor drive, means for sensing roll force of the second roll set, means for adjusting the speed of the first motor drive, and means responsive to both of said sensing means for computing the loading of the first motor drive before and after workpiece entry to the second rolls, said computing means generating an error signal to control said motor speed adjusting means and maintain matched speeds for the first and second rolls during workpiece transport through the mill.

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50 CHARLES W. LANHAM, *Primary Examiner*.
A. RUDERMAN, *Assistant Examiner*.