COMBINATION GAGE AND GUIDE CONTROL FOR STRIP MILLS

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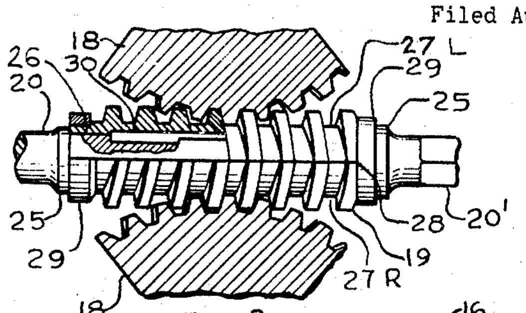

FIG.-2

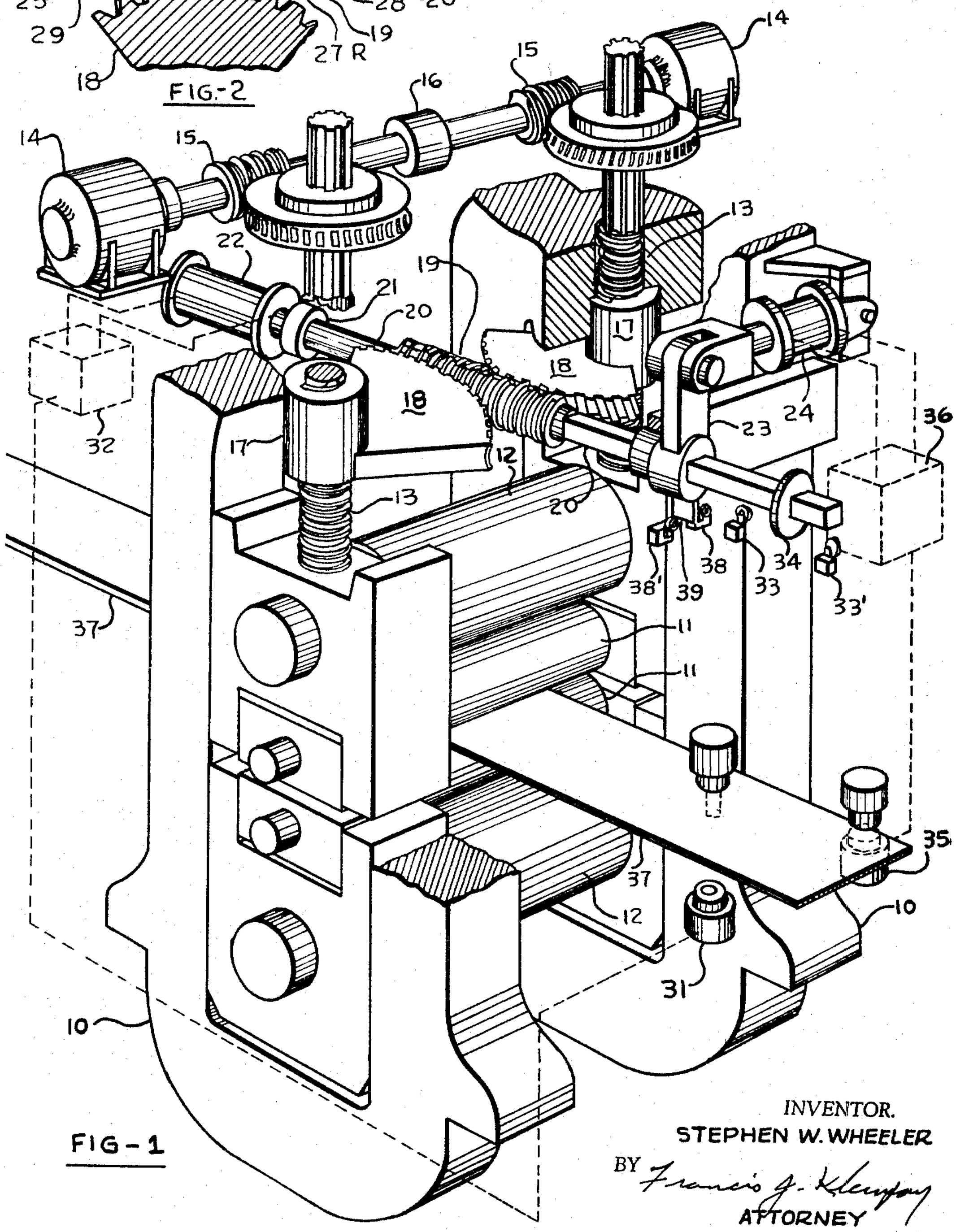

FIG-1

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COMBINATION GAGE AND GUIDE CONTROL FOR STRIP MILLS

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ABSTRACT OF THE DISCLOSURE

A combined gage and level control for a pair of work rolls of a strip rolling mill. A motor drive causes a pair of screwdowns and reacting nuts to act on opposite ends of one roll to vary the spacing between rolls. A second independent drive, including left and right hand threads driving correspondingly threaded arcuate segments integral with said reacting nuts, cause the nuts to turn in opposite directions to change the parallelism between the rolls, without affecting their average spacing, so as to properly guide the strip.

This invention relates to metal rolling mills, and more particularly to improvements for controlling both the gage and camber of metal strip and plate being rolled in such mills. In modern practice, both the speed of rolling and the maintenance of close tolerance in the gage and the product have assumed great importance, and to effect the production of large tonnages in a short time, particularly of strip, it is common practice to utilize continuous mills having a multiplicity of individual rolling stands, usually six in number. The maintenance of close gage control at high speed presents, in itself, serious problems, and in my U.S. Patent No. 2,961,901 I have proposed a quick-acting low-inertia system for almost instantaneously varying the spacing between the work rolls of the stands in order that a very close control over the gage while the strip being run may be achieved even when the stands are operating at quite high speeds.

Another of the problems encountered in the rolling of strip is the guidance of the strip through the rolling stand or stands, and this problem becomes quite serious in multi-stand installations operating at high speed. It is necessary to keep the strip spaced well inwardly from the inner surfaces of the side housings or frames on the stands so as to avoid accidental collision of the side edges of the strip with the inner surfaces of the housings or frames. Also, it is desirable that the strip be kept straight and true from the slab or bar to the finished coiler to effect precise alignment of the side edges of the convolutions of the finished coil and to achieve uniformity of product throughout the entire axial length of the strip. It is known that the strip can be guided by controlling the spacing of the work rolls transversely across the strip, and this has heretofore been accomplished by individually actuating the screwdowns on opposite sides of the mill stands. However, this arrangement has heretofore required extensive control apparatus, close attention by the operator, and is much too slow in its execution to effectively cope with the speed of modern mills. The present invention overcomes these difficulties by providing an exceedingly simple and very quick-acting arrangement for varying the relative level of the work rolls of the mill stand in response to deviation in the running path of the strip.

A further object of the invention is the provision of improved side edge control for strip mill having the low-inertia and quick-acting characteristic indicated above which is readily combinable with the improved gage control of my aforementioned U.S. Patent No. 2,961,901, whereby the cost of applying the present improvement to a rolling mill stand is kept to a minimum. Also, since the

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system of the prior patent is useful also for the rapid unloading and reloading of the mill stand, the present invention achieves the further beneficial combination of means to rapidly and accurately guide the strip while yet enabling the work rolls of the stand to be very quickly opened and closed to allow for the passage of cobbles, welds, etc.

As will appear from the following specification, it is apparent that the features of this invention will find substantial utility in plate mills, in addition to strip mills, wherein accuracy of thickness and freedom of camber is sometimes of extreme importance.

The above and other objects and advantages of the invention will become apparent upon consideration of the following specification and the accompanying drawing wherein there is disclosed a preferred embodiment of the invention.

In the drawing:

FIGURE 1 is a perspective view, with parts broken away, of a four-high rolling mill stand constructed in accordance with the principles of the invention, and with certain of the control instrumentalities being shown schematically in dotted outline; and

FIGURE 2 is an elevation, partly in section, of a composite worm utilized in the assembly of FIGURE 1.

In the drawing, reference numerals **10** designate the side housing of a conventional four-high strip rolling mill stand having upper and lower working rolls **11** and upper and lower backing rolls **12**. A screwdown **13** is provided for each of the housings **10** whereby the rolling space between the work rolls **11** and the parallelism between these work rolls may be readily controlled. For this purpose a conventional screwdown motor **14** operating through a worm **15** is provided for each of the screwdowns **13**, a remotely controlled clutch **16** interconnecting the two worms to permit the two screwdowns to be driven either simultaneously or independently, as desired, all in accord with conventional practice in the art.

As more fully illustrated and described in the aforesaid U.S. Patent No. 2,961,901, a large nut **17** is received on each of the screwdowns **13** and has rotative relation to the housing **10** as well as a rigidly attached gear segment **18** which projects inwardly toward each other. It should be obvious that if the nuts **17** are held in nonrotative condition the rise and fall of the screwdowns **13** will be determined solely by the actuations of the motors **14**; whereas, if the latter are held de-energized and the segments **18** moved, the screwdowns will raise and lower a slight amount determined by the direction and extent of movement of the segments. In the aforesaid prior patent, the last-mentioned characteristic is availed of to impart quick-acting linear movements to the screwdowns in substitution for or possible additive to such movements imparted by the motors **14**, and this is accomplished by inserting a double rack between the two gear segments of the rotatable screwdown nuts and imparting rectilinear movement to the rack by a double-acting hydraulic cylinder.

In accordance with the present invention, however, the above referred to last-mentioned characteristic is availed of in a novel and wholly practical manner to not only impart quick-acting longitudinal movement to the screwdowns in the same direction for gage control but to also impart quick-acting movements to the screwdowns in opposite directions to rapidly effect variations in parallelism between the work rolls for strip guiding purposes. These functions are accomplished by a specially constructed worm **19** which replaces the double rack in the prior patent and which will be hereinafter described in detail. The worm **19** is keyed onto a shaft **20** which through an anti-friction rotary joint **21** is coupled with a double-acting hydraulic cylinder 22. Cylinder 22 corresponds generally in function and structure with the cylinder 41 of the prior patent, and it should be obvious that while the joint 21 herein permits relative rotation between the shaft 20 and the piston rod of cylinder 22 it does not permit relative axial movement between these parts. Also, as will appear later, the worm 19 is restrained against any axial sliding movement with respect to the shaft 20.

The end of the shaft 20, which is opposite the joint 21, is splined or squared as shown at 20′ to receive the hub of a lever 23 which is actuated by a double-acting hydraulic cylinder 24. Means, not particularly shown, is provided to restrain movement of the lever 23 in a direction parallel with the principal axis of the shaft 20, 20′ but it should be understood that this shaft may have axial movement with respect to the lever and that it is rotated by rocking movement of the lever. Reference should now be had to FIGURE 2 to determine the construction of the composite worm 19.

Shaft 20 is formed with a pair of spaced and inwardly facing annular abutments 25 between which is a turned section 26 of substantially lesser diameter than the outer diameters of the abutments 25. Lying on the surface 26 and abutting against annular stops 25 is a pair of semi-sleeves 27L and 27R which are formed on their outer peripheries with worm teeth or convolutions, those on part 27L being left-handed and those on part 27R being right-handed. The parts 27L and 27R are accurately dimensioned and fitted to have interengaging abutting contact in a common plane but at diametrically opposed locations as indicated at 28. When thus assembled, the parts 27L and 27R form, in effect, a thick sleeve about the surface 26 and between the abutments 25 and with worm threads or convolutions of one hand on 180° of the periphery of the sleeve and similar threads or convolutions of the other hand on the remaining 180° of the sleeve.

The two parts 27L and 27R are connected together and mounted on the shaft 20 between the abutments 25 by means of heavy rings 29 which are shrunk or screwed onto cylindrical surfaces properly formed on the end portions of these parts. Elongated keys 30 partially received in ways cut into the surface 26 of the shaft 20 and partially received in ways cut in the parts 27L and 27R are provided to insure rotation of the composite worm 19 along with rotation of the shaft 20. Worm 19 is preferably manufactured by turning or cutting the teeth or convolutions in two identical tubular blanks, one with right-hand threads or convolutions and the other with left-hand threads or convolutions. Thereafter, these blanks are slit longitudinally and a half section of right-hand threads is mated with the half section of left-hand threads in mounting the composite worm on the shaft 20 as explained above. Now, referring back to FIGURE 1, it should be understood that the segments 18 which are attached to or integral with the nut 17 have worm teeth on their peripheries which complement the right and left-hand threads on the worm 19. The plane of division between the two halves of the worm 19 is generally vertical and the extent of rotation of the shaft 20, 20′ is considerably less than 90° in either direction from its midposition so that there is no danger of jamming in the drive. It will be obvious that as the worm 19 is rotated in either direction from its centered or midposition one of the nuts 17 will be rotated in one direction while the other of the nuts 17 will be rotated in the opposite direction. Thus, upon actuation of the cylinder 24, in either direction, one of the screwdowns 13 will be moved in one vertical direction while the other of the screwdowns is moved in the other vertical direction. This tilts the upper work roll 11 in one direction or the other to cause the strip being rolled in the mill stand to be guided one way or the other in the horizontal plane of its path for the purpose explained initially above.

The cylinder 22 is controlled by a thickness gage 31 acting through an amplifier and electric hydraulic transducer indicated herein schematically by reference numeral 32 in the manner more fully explained in the aforementioned prior patent. Also, in accordance with the disclosure of said prior patent the main screwdown motors 14 are energized in proper direction when the piston in cylinder 22 approaches the end of its stroke in either direction. Limit switches 33 and 33′ and a disk-like actuator 34 carried by the shaft 20′ may be provided for this purpose. Of course, in a practical installation, means is provided to control directly the energization of motors 14 for initial or coarse adjustment of gage and when clutch 16 is energized to separate motors 14 to provide an initial leveling of the top working roll 11, all as is well understood in the art.

I provide, in conjunction with the composite worm 19 and its actuating cylinder 24, an edge sensing device 35 which acts through an amplifier and electrical hydraulic transducer 36 to control the hydraulic energization of the cylinder 24. The edge sensor may be of any suitable kind of which many are known in the art, including the kind which establishes a potential in accordance with the degree of interruption of a light pencil directed toward a light-sensitive cell. Thus, in FIGURE 1, the electrical circuitry may be calibrated and adjusted to hold steady the hydraulic energization of the cylinder 24 when the edge of the strip exactly bisects the beam of light impinging on cell 35. If the strip swerves to interrupt more of the beam, the resultant change in potential fed to the amplifier and transducer 36 to actuate the cylinder 24 in such direction as to tilt the upper work roll 11 to thin out the side of the strip which is contiguous to the sensor 35 whereby the strip will be guided away from its overtravel back into its proper path. In the drawing, the strip being worked is indicated by reference numeral 37. If, however, the directional deviation is the other way, too much light will reach the cell 35 and the correction via the cylinder 24 will be in the opposite direction. Of course, suitable means, not shown herein, may be employed to control the sensitivity and antihunting characteristics of the edge positioning control. Also, it should be understood that the above outlined type of edge control is exemplary only since various other systems for this purpose are known, including those having sensors at both edges of the work.

In view of the above-mentioned limitation on the extent of rotation of the composite worm 19, I may provide limit switches 38 and 38′ for actuation by an arm 39 depending from the shaft 20 and operating through suitable controls, not shown herein, to actuate the clutch 16 and energize the motors 14 in proper directions to effect tilting of the upper work roll 11 beyond the extent possible by mere energization of the cylinder 24. It will be obvious that suitable means, also not shown herein, will be provided to automatically bring the piston in cylinder 24 to its midposition when any level control is being effected by one or both of the motors 14 so that thereafter the tilt control of this invention may be operative to take over automatic command of the tilting of the upper work roll, As indicated in the drawing and as heretofore explained, the plane between the two halves of the worm 19 will be vertical and parallel with the screwdowns when the piston in cylinder 24 is in midposition.

It should now be apparent that I have provided an improved combination gage and guide control for strip mills which accomplishes the objects set out first above. By combining both control functions in a unitary control assemblage it is possible not only to add these control features to the mill at low cost but also in such manner that the otherwise normal arrangement of the mills and clearance spaces about their essential components is not impeded and in such manner that the control directives may be provided with relatively simple and inexpensive circuitry the production of which is well within the capabilities of technicians skilled in the present state of the art. Of greater importance, however, is that both the spacing between the work rolls of the mills and the relative tilt between the respective pairs of work rolls is accomplished by low-inertia high-speed apparatus which provides the capability of much more precise control even when the mills are operated at very high production speeds. The absolute independency of the two control functions is of further advantage as will be understood since the relative reverse action of the two screwdown nuts upon floating actuation of the leveling control cylinder has no effect whatever on the average gage or opening of the pairs of work rolls. Also, changes in such gage or opening may be instantaneously accomplished without altering the level adjustments.

Having thus described my invention, I claim:

1. A combined gage and level control for a pair of work rolls of a strip rolling mill comprising a pair of axially movable screwdowns for acting on the opposite ends of one of said rolls, a reacting nut for each of said screwdowns revolvably mounted but restrained against axial movement whereby the positions of the said ends of one of said work rolls may be adjusted by rotating the screwdowns or alternatively by rotating said nuts, a double-acting motor and a driving device connected thereto for actuating said nuts in unison to thereby vary the spacing between said rolls without altering the relative parallelism therebetween, and a second double-acting motor connected to said device for actuating said device in such manner that said nuts are actuated in opposite directions to change the parallelism between said rolls without affecting the average spacing therebetween.

2. Control apparatus according to claim **1** further characterized in that said driving device comprises a rectilinearly movable member positioned between and having simultaneous driving connections with said nuts whereby said nuts are rotated in opposite directions in unison, said screwdowns having threads of opposite hand whereby such unitary rotation of said nuts moves the ends of the said one of said rolls upwardly and downwardly in unison, and further characterized in that the said connection between said second motor and said device is operative to rock said device about its rectilinear axis, and further including such interconnections between said device and said nuts that rocking movement of said device about said axis rotates said nuts in the same direction to thereby change the relative level of said work rolls.

3. Control apparatus according to claim **1** further characterized in that said screwdowns have threads of opposite hand, said driving device being a rectilinearly movable member positioned between said nuts and having driving connections with both of said nuts, driving means to rotate said screwdowns either individually in either direction or simultaneously in opposite directons, and including further control means to rotate one of said screwdowns individually upon said second motor being actuated a predetermined extent in one direction from its mid operating position.

4. Control apparatus according to claim **2** further characterized in that said rectilinearly movable member comprises a worm having threads of one hand on half of its circumferential extent and threads of opposite hand on the other of its circumferential extent, and said nuts having worm wheel segments thereon with threads of such hand as to properly fit the oppositely handed threads of said worm.

5. Control apparatus according to claim **4** further characterized in that said first mentioned motor is aligned with said worm, and further including a rotatable joint between said first mentioned motor and said worm to move said worm rectilinearly while yet permit said worm to be rotated to opposite directions about its rectilinear axis.

6. Control apparatus according to claim **5** further characterized in that the connection between said second motor and said worm includes means to rock said worm about its rectilinear axis.

7. Control apparatus according to claim **1** further characterized in that the first mentioned double-acting motor is of the fluid pressure type and in that said second double-acting motor is also of the fluid pressure type.

8. A level control for a pair of work rolls of a strip rolling mill comprising a pair of screwdowns for acting on the opposite ends of one of the rolls, a reacting nut for each of the screwdowns whereby the position of the ends of one of the work rolls may be adjusted by activating the screwdowns or alternatively by rotating the nuts, a fluid-pressure motor and a driving device therefor for rotating the nuts in such manner that they are actuated in different directions to change the parallelism of the rolls.

9. Control apparatus according to claim **8** further characterized in that said screwdowns have threads of opposite hand, said driving device being a rectilinearly movable member positioned between said nuts and having driving connections with both of said nuts, and driving means to rotate said screwdowns either individually in either direction or simultaneously in opposite directions.

10. Control apparatus according to claim **8** further characterized in that said rectilinearly movable member comprises a worm having threads of one hand on half of its circumferential extent and threads of opposite hand on the other of its circumferential extent, and said nuts having worm wheel segments thereon with threads of such hand as to properly fit the oppositely handed threads of said worm.

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