

April 12, 1966 **W. L. ROBERTS** **3,245,241**
METHOD AND APPARATUS FOR MAINTAINING UNIFORM
TENSILE STRESS IN STRIP
Filed July 22, 1963 2 Sheets-Sheet 1

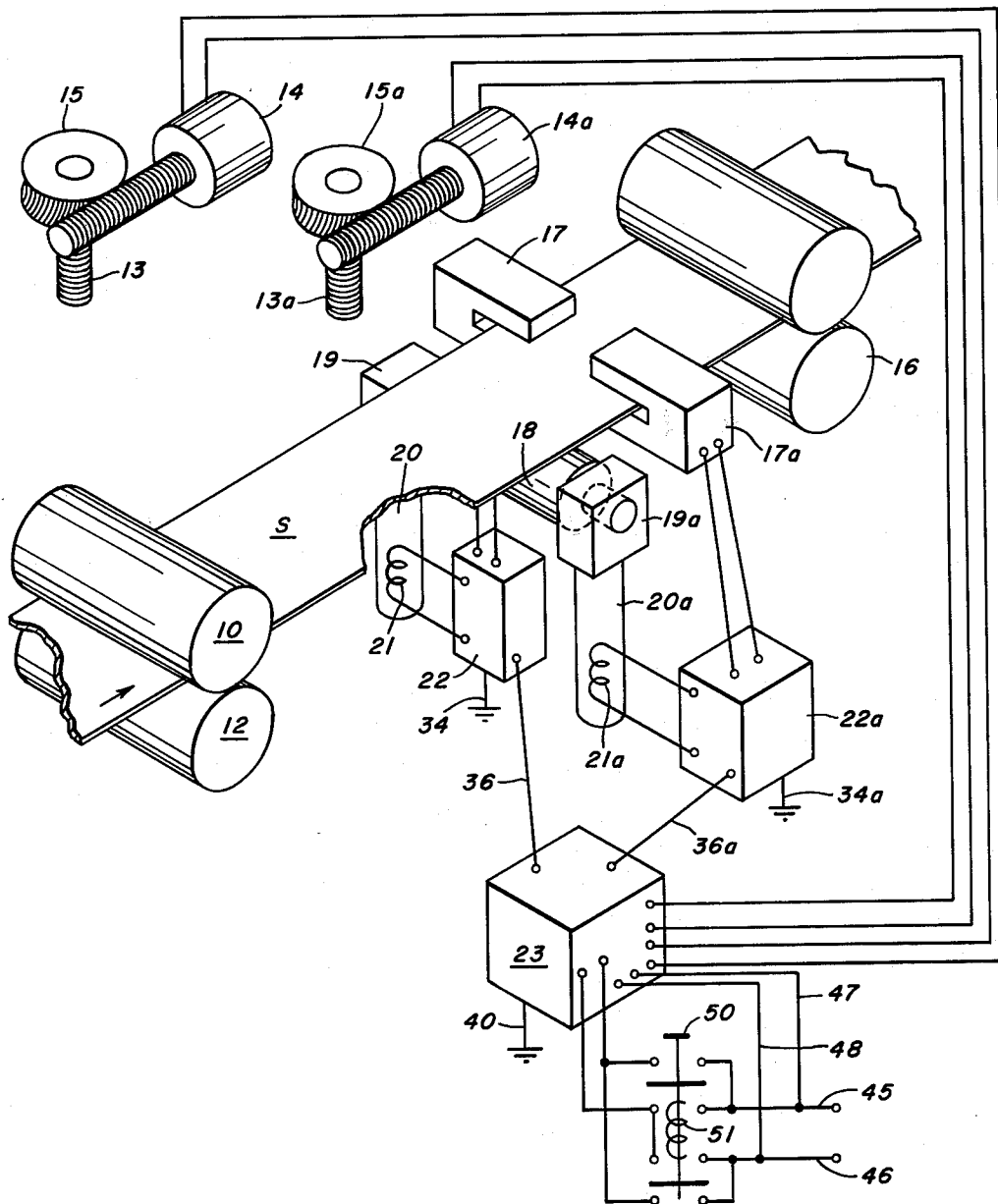
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FIG. 1.



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FIG. 2.

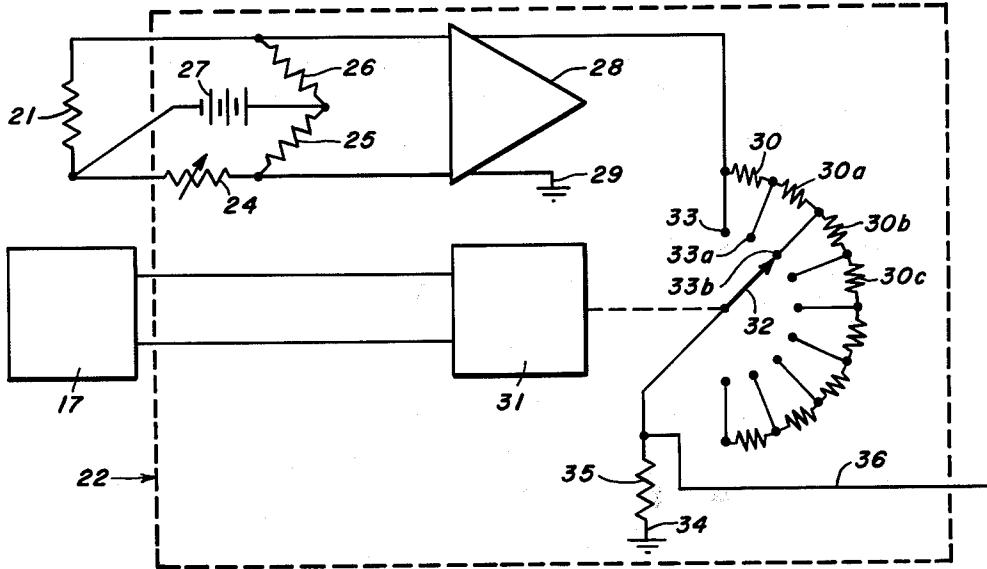
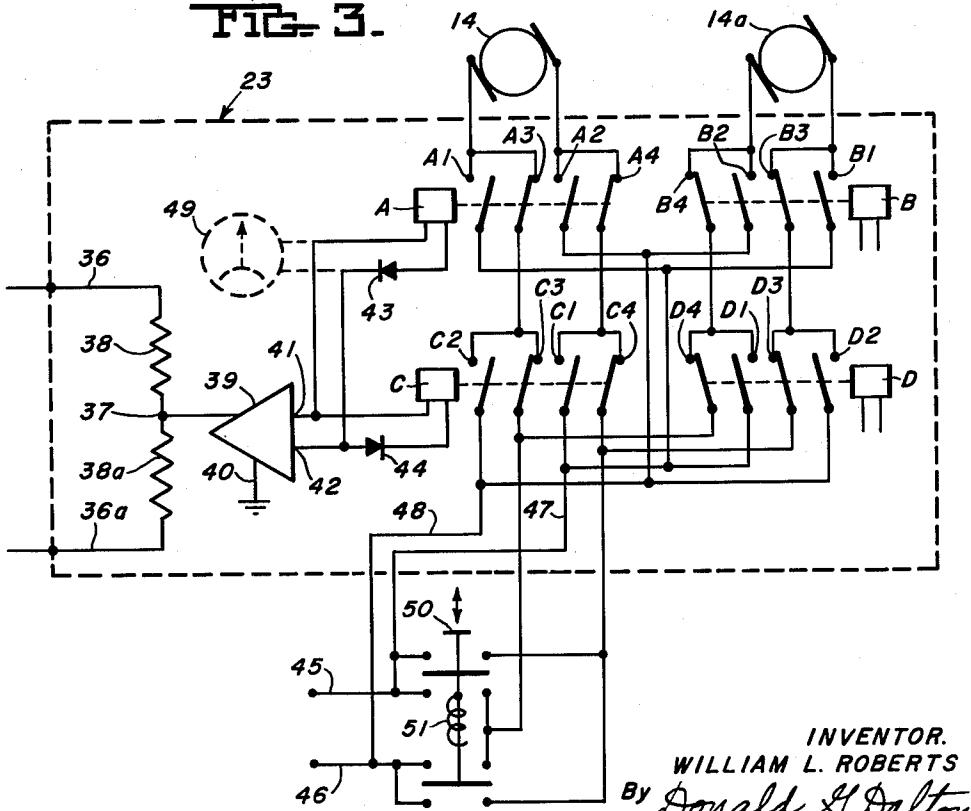


FIG. 3.



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1

2

3,245,241

METHOD AND APPARATUS FOR MAINTAINING UNIFORM TENSILE STRESS IN STRIP

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10 Claims. (Cl. 72-9)

This invention relates to a method and apparatus for maintaining uniform tensile stress at opposite sides of a metal strip during a rolling operation.

As metal strip is rolled, it is pulled through work rolls under tension. The rolls reduce the strip in stages to a predetermined thickness. If the tensile stress at opposite sides of the strip is not uniform during rolling, the strip may be defective. One form of defect likely to occur is "camber," which refers to a sideways bending; that is, one side edge of a cambered strip is convex and longer than the other. When metal strip is used in coil form, for example in the manufacture of containers, it is particularly important that the strip be free of camber. It is also possible that nonuniform tensile stresses in strip may cause metallurgical defects, since the strip is not worked uniformly.

An object of the present invention is to provide a method and apparatus for determining whether tensile stresses are uniform at opposite sides of a strip during rolling, thus furnishing information needed to avoid defects caused by nonuniform stresses.

A further object is to provide a method and apparatus of the foregoing type which automatically adjust a strip-rolling stand to maintain uniform stress in opposite sides of a strip.

A more specific object is to provide an improved method and apparatus for preventing nonuniformities in stress at opposite sides of a strip during rolling in which the ratio of tension to thickness is measured at each side, the two ratios are compared, and the screwdown motors of the roll stand are operated automatically to eliminate any differences in the ratios.

In the drawing:

FIGURE 1 is a diagrammatic perspective view of a roll stand equipped with an apparatus for maintaining uniform stress in accordance with my invention;

FIGURE 2 is a schematic wiring diagram of a ratio-computing device embodied in the apparatus; and

FIGURE 3 is a schematic wiring diagram of a ratio-comparing and control device embodied in the apparatus.

FIGURE 1 shows diagrammatically a conventional strip-rolling stand which includes upper and lower work rolls 10 and 12, screws 13 and 13a at the left and right operatively connected with the rolls for regulating their spacing, reversible screwdown motors 14 and 14a, and gearing 15 and 15a connecting the motors with the respective screws. Since the mechanical connection between the screws and rolls is conventional, no showing is deemed necessary. A cooperating tensioning device 16, for example another set of rolls, pulls a continuous metal strip S through the work rolls 10 and 12.

In accordance with the present invention, I mount thickness gages 17 and 17a in locations to measure the strip thickness at the left and right sides respectively, preferably about halfway between each edge of the strip and the center line, and on the exit side of the work rolls 10 and 12. These gages can be of conventional construction, preferably of the X-ray or equivalent radiation type, and they generate electric signals proportional to the strip thickness. I connect the gages in a way that the potential of the signals therefrom increases as the strip becomes thicker, as known in the art. The strip also runs over a tension roller 18 journaled in bearings 19 and 19a at the left and right respectively and located on the exit side

of the work rolls 10 and 12 but ahead of the tensioning device 16. Bearings 19 and 19a are mounted on posts 20 and 20a, which carry conventional electric strain gages 21 and 21a respectively. Tension in strip S applies compressive loads to posts 20 and 20a. The magnitude of load on each post, and hence the deformation or strain, are proportional to the tension in each side of the strip. The electrical resistance of each strain gage is at a maximum when the strip is free of tension and there is no compressive load on the posts. The greater the tension, the less the resistance.

I connect the thickness gage 17 and strain gage 21 to a ratio-computing device 22, hereinafter described. This device continuously computes the ratio of tension to thickness in the left half of the strip. Similarly I connect thickness gage 17a and strain gage 21a to a ratio-computing device 22a, which computes this ratio for the right half. The ratio of tension to thickness in each half of the strip is an approximation of the tension per unit of cross-sectional area in that half, or the tensile stress therein. If the two ratios are unequal, the stress in the two sides of the strip is not uniform. I connect the two ratio-computing devices 22 and 22a to a ratio-comparing and control device 23, hereinafter described, and I connect this device to the two screwdown motors 14 and 14a. Whenever the ratios become unequal, the control device completes circuits to operate the two motors in opposite directions. Thus the work rolls 10 and 12 move a little closer together at one end and farther apart at the other. The thickness of the strip decreases slightly at one side and increases at the other until the two ratios become equal.

FIGURE 2 shows in more detail one example of a circuit I can use in the ratio-computing device 22. The circuit includes a bridge, the arms of which are the strain gage 21, a variable resistor 24 and two fixed resistors 25 and 26. I connect a power supply 27 and a conventional amplifier 28 across opposite terminals of the bridge in the usual way. I connect the respective output terminals of the amplifier to a ground 29 and to one end of a series of resistors 30, 30a 30b etc. of equal value. The ratio-computing device also includes a conventional digital voltmeter 31 to which I connect the thickness gage 17. One example of a suitable digital voltmeter is available commercially from Non-Linear Systems, Inc., Del Mar, California, as the NLS Model 481 and is described in a printed publication by the supplier, Catalog 356. I mechanically connect the digital voltmeter to a rotary switch arm 32, which is engageable with a succession of contacts 33, 33a, 33b, etc. connected between the resistors 30, 30a, 30b, etc. I connect arm 32 to a ground 34 through a resistor 35, which is relatively small as compared with resistors 30, 30a etc. I connect an output conductor 36 between arm 32 and resistor 35.

I adjust resistor 24 to a value equal to that of the strain gage when there is no tension in strip S. Under this condition the bridge is balanced and no current flows through the amplifier. As the strip is tensioned and the resistance offered by the strain gage diminishes, the bridge becomes unbalanced and current commences to flow. The greater the tension, the greater the current. The digital voltmeter 31 positions the rotary switch arm 32 in accordance with the thickness of the strip as measured by gage 17. The thicker the strip, the greater the number of resistors 30, 30a, etc. connected between amplifier 28 and ground 34. The magnitude of current which flows through resistor 35 varies directly with the tension in the left half of the strip and inversely with the thickness of the left half, and hence is proportional to the ratio of tension to thickness. The voltage drop across resistor 35 is proportional to the current, whereby conductor 36 carries a voltage signal proportional to the ratio or to

the stress in the left half of the strip. The ratio-computing device 22a operates similarly, except that the connections to the output terminals of the amplifier are reversed to produce a voltage signal of the opposite polarity in its output conductor 36a. In the interest of simplicity, I have not repeated the showing.

FIGURE 3 shows in more detail one example of a circuit I can use in the ratio-comparing and control device 23. The device includes a D.-C. voltage amplifier 39 and four relays A, B, C and D. I connect the two conductors 36 and 36a from the ratio-comparing device 22 and 22a to a common terminal 37 through resistors 38 and 38a. I connect terminal 37 to one input terminal of amplifier 39 and connect the other input terminal of the amplifier to a ground 40. The amplifier has output terminals 41 and 42, to which I connect the coils of relays A and B in series with a rectifier 43. Similarly I connect the coils of relays C and D to these output terminals in series with a rectifier 44 arranged to conduct current in the opposite direction from rectifier 43. As long as the ratios of tension to thickness in the two sides of strip S are equal, the potential on conductors 36 and 36a are equal and opposite. The voltage amplifier 39 transmits no signal, and all the relays remain deenergized. If the ratio on the left side of the strip exceeds that on the right side, the potential on conductor 36 becomes greater and the output terminal 41 becomes positive with respect to 42, whereupon relays A and B are energized. Similarly, if the ratio on the right side exceeds that on the left, relays C and D are energized.

Relay A has two front or normally open contacts A₁ and A₂ and two back or normally closed contacts A₃ and A₄. The other relays have similar contacts designated by the same subscripts. I connect the control device to an outside D.-C. power source via lines 45 and 46. A conductor 47 extends from line 45 to one side of each front contact A₁, B₁, C₁ and D₁. Similarly a conductor 48 extends from line 46 to one side of each front contact A₂, B₂, C₂ and D₂. I connect the other sides of each contact of relays A and C to the terminals of the left screwdown motor 14, and the other sides of each contact of relays B and D to the terminals of the right screwdown 14a. When relays A and B are energized, motor 14 is energized in a direction to move the left ends of the work rolls 10 and 12 farther apart, and motor 14a is energized in a direction to move the right ends closer together. Thus the thickness of the right side of the strip diminishes and the thickness on the left side increases until the ratios of tension to thickness become equal. The reverse action occurs when relays C and D are energized. Preferably I also connect an indicator 49 across the output terminals 41 and 42 to shown any inequality in the ratios. Optionally I can use this indicator to adjust the roll spacing by manual actuation screwdown motors, and omit the relays which actuate these motors automatically.

I connect a manually operable double-throw, multi-contact switch 50 between lines 45 and 46 and the back contacts of the four relays. Normally a spring 51 holds switch 50 in an open position. Closing the switch in one direction energizes both screwdown motors 14 and 14a in the same direction to move the work rolls 10 and 12 closer together. Closing the switch the other way energizes both motors to move the rolls farther apart.

From the foregoing description it is seen that my invention affords a simple method and apparatus for maintaining uniform tensile stress in opposite sides of a strip during rolling. In this manner I successfully avoid camber in the strip. While my invention may cause slight variations in the thickness of the strip from side to side, this is a much less serious defect than camber. Normally specifications allow strip thickness to vary up to plus or minus 10 percent from the nominal thickness.

While I have shown and described only a single em-

bodiment of my invention, it is apparent that modifications may arise. Therefore, I do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

I claim:

1. In a rolling operation in which metal strip is pulled through a set of work rolls under tension to reduce its thickness, a method of maintaining uniform tensile stress in opposite sides of the strip comprising determining the ratio of tension in the strip to the thickness thereof at each side of the center line on the exit side of the rolls, and adjusting the thickness at each side of the strip to furnish equal ratios.

2. In a rolling operation in which metal strip is pulled through a set of work rolls under tension to reduce its thickness, a method of maintaining uniform tensile stress in opposite sides of the strip comprising measuring the thickness of the strip and the tension therein at each side of the center line on the exit side of the rolls, computing from these measurements the ratio of tension to thickness at each side of the strip, comparing the two ratios, and adjusting the thickness at each side to furnish equal ratios.

3. In a rolling operation in which metal strip is pulled through a set of work rolls under tension to reduce its thickness, a method of maintaining uniform tensile stress in opposite sides of the strip comprising measuring the thickness of the strip at locations about halfway between each side edge and the center line on the exit side of the rolls, measuring the tension in each side of the strip, computing the ratio of tension to thickness at each side, and adjusting the rolls to bring them closer together at one end and farther apart at the other whenever the ratios are unequal, thereby changing the thickness at each side of the strip to furnish equal ratios.

4. In a strip-rolling mill which includes a set of work rolls, adjustable means operatively connected with said rolls at each end for varying the spacing therebetween, and a cooperating tensioning device spaced from said rolls for pulling metal strip therethrough under tension, the combination therewith of an apparatus for maintaining uniform tensile stress in opposite sides of the strip comprising means for computing the ratio of tension in the strip to the thickness thereof at each side of the center line on the exit side of said rolls, and means operatively connected with said computing means and with said adjustable means for operating the latter when the ratios are unequal and thereby adjusting the strip thickness to furnish equal ratios.

5. In a strip-rolling mill which includes a set of work rolls, adjustable means operatively connected with said rolls at each end for varying the spacing therebetween, and a cooperating tensioning device spaced from said rolls for pulling metal strip therethrough under tension, the combination therewith of an apparatus for maintaining uniform tensile stress in opposite sides of the strip comprising means for measuring the thickness of the strip at each side of the center line on the exit side of said rolls, means for measuring the tension in the strip at each side of the center line, means operatively connected with said measuring means for computing the ratio of tension to thickness at each side, and means operatively connected with said computing means for comparing the two ratios and thereby determining whether the stress is uniform at opposite sides.

6. In a strip-rolling mill which includes a set of work rolls, adjustable means operatively connected with said rolls at each end for varying the spacing therebetween, and a cooperating tensioning device spaced from said rolls for pulling metal strip therethrough under tension, the combination therewith of an apparatus for maintaining uniform tensile stress in opposite sides of the strip comprising means for measuring the thickness of the strip at each side of the center line on the exit side of said rolls, means for measuring the tension in the strip at each

5

side of the center line, means operatively connected with said measuring means for computing the ratio of tension to thickness at each side, means operatively connected with said computing means for comparing the two ratios, and a control device operatively connected with said comparing means and with said adjustable means for operating the latter when the ratios are unequal and thereby adjusting the strip thickness to furnish equal ratios.

7. In a strip-rolling mill which includes a set of work rolls, adjustable means operatively connected with said rolls at each end for varying the spacing therebetween, and a cooperating tensioning device spaced from said rolls for pulling metal strip therethrough under tension, the combination therewith of an apparatus for maintaining uniform tensile stress in opposite sides of the strip comprising a pair of gages positioned to measure the thickness of the strip on the exit side of said rolls at locations about halfway between each side edge of the strip and the center line, means for measuring the tension in the strip at each side of the center line, means operatively connected with said gages and with said measuring means for computing the ratio of tension to thickness at each side, means operatively connected with said computing means for comparing the two ratios, and a control device operatively connected with said comparing means and with said adjusting means for operating the latter to bring said rolls closer together at one end and farther apart at the other whenever the ratios are unequal, thereby changing the thickness at each side of the strip to furnish equal ratios.

8. A combination as defined in claim 7 in which said tension-measuring means includes a tension roller over which the strip runs on the exit side of said work rolls, bearings in which opposite ends of said tension roller are

6

journaled, posts supporting said bearings, and electric strain gages mounted on said posts.

9. A combination as defined in claim 7 in which said computing means for each side includes a bridge circuit, one of the arms of said circuit being a strain gage the electric resistance of which varies with the tension in the corresponding side of the strip, an amplifier connected across said bridge for transmitting current varying with the tension, a series of resistors connected to said amplifier, a digital voltmeter connected to the thickness gage on the corresponding side of the strip, an arm operatively connected with said voltmeter for cutting in a number of resistors varying with the strip thickness, a resistor in series with said arm, and a conductor connected with said last-named resistor for transmitting a voltage signal proportional to the ratio.

10. A combination as defined in claim 7 in which said comparing means includes a D.-C. voltage amplifier connected to receive voltage signals of opposite polarity from the computing means for each side of the strip, and said control device includes relays for establishing current paths which operate said adjustable means, and rectifiers in series with said relays and said amplifier for selectively energizing said relays when the voltage signals are unequal.

References Cited by the Examiner

UNITED STATES PATENTS

3,006,225	10/1961	Mamas	72—12
3,078,747	2/1963	Pearson	72—9
3,081,651	3/1963	Roberts	72—9

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