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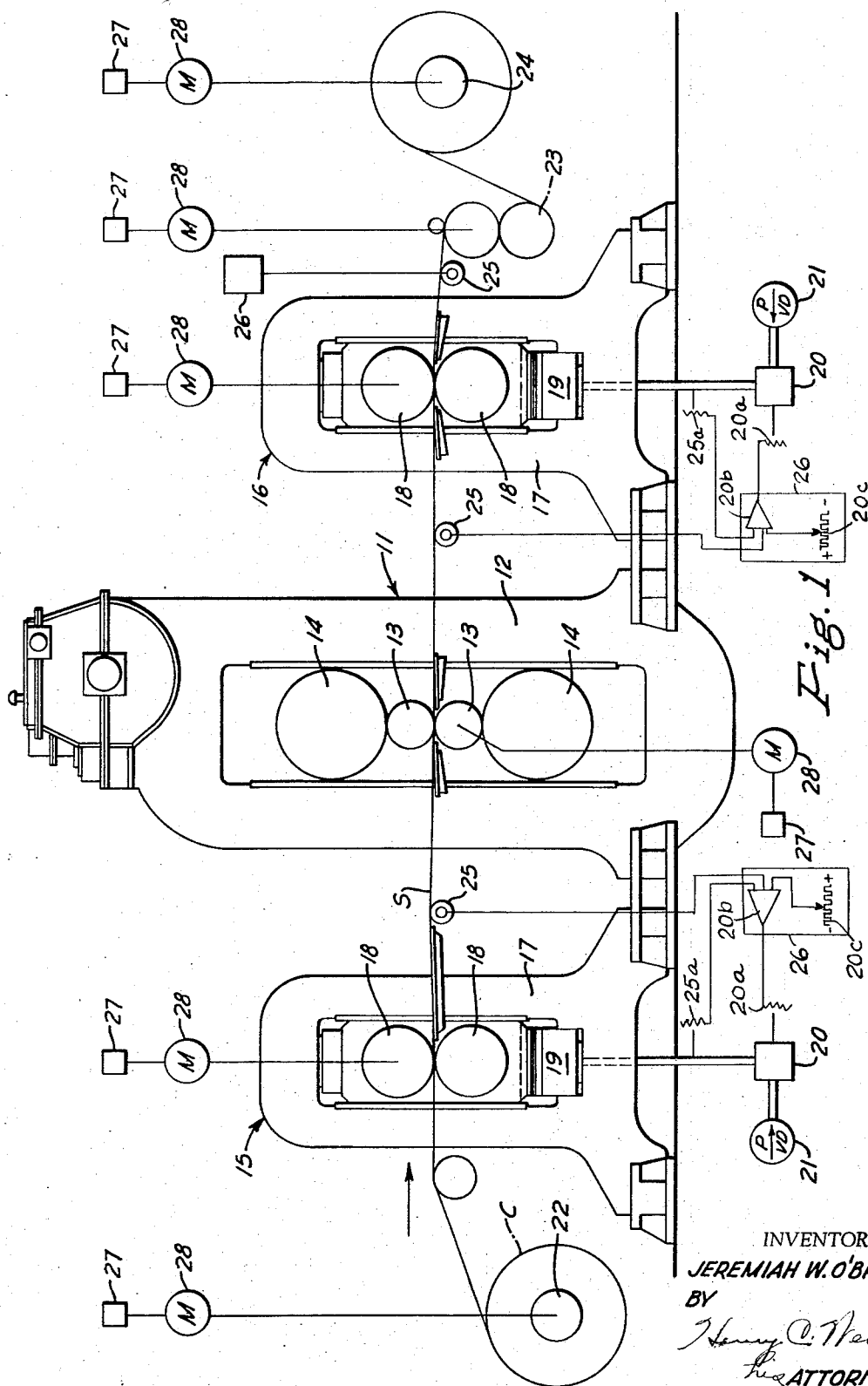
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3,292,402

METHOD AND APPARATUS FOR ROLLING FLAT STRIP

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

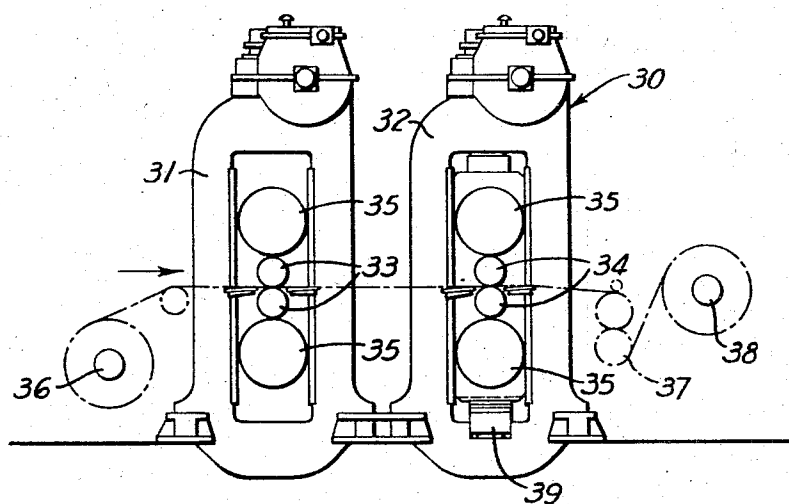


Fig. 2

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METHOD AND APPARATUS FOR ROLLING FLAT STRIP

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13 Claims. (Cl. 72-17)

This invention relates to a method of and apparatus for rolling strip material and more particularly to rolling such material in a manner that flatness thereof is improved and assured.

As an incident to strip being reduced by rolling to very thin gauges, there is created an increasing tendency of the thin strip to be rolled with buckles or waves, either at the edges or center portions, depending on which of these portions are over-rolled. The term "over-rolled" or "over-rolling" refers to the condition wherein certain transverse portions of the strip are reduced, i.e., elongated more than other portions thereof. One of the primary causes of over-rolling of strip resides in the deflection during rolling of the working rolls along their lengths so that, unless compensated for, the distance between the cooperative working surfaces of these rolls vary. Another primary cause of strip over-rolling is due to the shape, i.e., the non-flat condition of the incoming strip and the degree of the varying thickness across the width of such strip as it enters the mill. It sometimes occurs that a strip entering the mill will have good flatness characteristics but the roll deflections of the mill being not consonant with the varying cross sectional thickness of the strip will cause the strip to be rolled non-flat. Hereinafter strip having this buckled condition will be referred to as "non-flat" strip and strip wherein this condition is alleviated or corrected in part or totally, as "flat" strip.

It has long been known in rolling mill practice that the non-flat condition of strip is beneficially affected by applying tension to the strip. In certain rolling operations, while not necessarily applied for the purpose under discussion, tension is applied to the strip between stands and in other cases after the strip leaves the mill. In the latter case a tension reel may be employed for this purpose. However, in the first case, i.e., interstand tension, when tension is so employed, as an incident to the operation of the mill, the flatness obtained under the influence of the tension may be lost partially or totally when the strip is reduced in the last pass, if a reduction is to be taken. In any event the advantage may be nullified by reason of the differential forces imposed in the strip during its coiling, the latter being caused by eccentric loading and rotation of the reel and coil supported thereby, and the circumferential unevenness in the build-up of the coil by reason of the strip having a varying cross-sectional thickness.

As will be more evident from the following portion of this specification, the present invention is addressed to a method of and apparatus for effectively employing tension in the rolling of strip material, wherein the flatness obtained thereby is preserved. More definitely, it relates to a method of and apparatus for rolling metallic strip material wherein the strip is characterized by adjacent transverse portions elongated to different degrees which condition causes the portion subject to greater elongation to become non-flat, the steps comprising: passing the strip between a first means for rolling the strip, passing the strip between a second means at least after the rolling step, wherein the strip is forceably contacted by said second means, controlling the contact pressure of said second means in a manner that little or no reduction in

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thickness of the strip is taken by said second means, controlling the operation of said first and second means to impose upon the strip a tension that will contribute to the rolling of the strip by said first means in a manner that the differences in elongation of said portions will be reduced and the non-flatness removed, imposing a tension upon the strip in a manner to militate against any reduction being taken by said second means, yet causing the strip to be tightly wound into a coil, and then coiling the strip.

While various mill arrangements can be employed to carry out the invention of this application, one form thereof provides a method of and apparatus for rolling flat strip and contemplates the employment of a 4-high reduction or temper mill in combination with two tandemly arranged pinch roll units, located on either side of and which are instrumental in imposing delivery tension and delivery and entry tensions on the strip during its rolling, but so constructed and operated so as to impart little or no reduction to the strip. Adjacent to one of the pinch roll units a tension bridle is provided by the use of which the delivery tension of the strip leaving the second pinch roll unit can be maintained at a value so as to militate against a reduction being taken by the second pinch roll unit, but yet allow a tension to be employed in the strip during coiling to assure that a tightly wound coil is formed. In the preferred form, the pinch roll units are equipped with relatively large diameter rolls, in addition to which constant exerting pressure means are employed so that the pressure condition at the bite of the pinch rolls can be maintained at a predetermined value to give the required optimum tension, but still assuring that little or no reduction will be taken by the pinch rolls.

Should the mill be a reduction mill instead of a temper mill, the inter-stand tension and rolling pressure, particularly of the last stand, will be controlled to effect little or no reduction in the last stand. Also, in a reduction mill where oil is employed to aid in reducing the strip, it may be desirable to employ a cleaning or detergent agent to remove the rolling oil from the strip, thereby minimizing the tendency of the last stand to reduce the strip.

In order to better appreciate the features of the present invention reference will be made to the accompanying drawings of which:

FIGURE 1 is a schematic elevational view of a 4-high rolling mill flanked on either side by two tension creating pinch roll units designed to carry out the features of the present invention, and

FIGURE 2 is a view similar to FIGURE 1 illustrating a two stand 4-high rolling mill designed to practice the present invention.

With reference first to FIGURE 1 of the drawings there is shown a 4-high stand 11 of ordinary construction which includes a pair of spaced-apart housing 12, only one of which is shown, into which there are received a pair of driven working rolls 13, each being supported by backing-up rolls 14 in a well-known fashion. On either side of the stand 11, there is arranged pinch roll units 15 and 16. These units constitute essentially a pair of spaced-apart housings 17, one of which is only shown, having windows into which there is received pairs of driven rolls 18, one of the rolls of each pair being at least adjustable relative to the other by single acting piston-cylinder assemblies 19 received in the bottom of each of the housings 17. As illustrated in this figure, the diameters of the rolls 18 are relatively large compared with the diameters of the working rolls 13, the diameters of the rolls 18 being such as to militate against any reduction being taken by them and for which reason in certain cases it may be desirable to employ iron rolls.

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In conjunction with each of the piston cylinder assemblies 19 of each pinch roll unit 15 and 16, a hydraulic system is provided. FIGURE 1 shows only the major elements of the systems which consists each of a remotely controlled variable delivery valve 20 and a variable delivery pump 21 designed to furnish a variable controlled pressure to the cylinder assemblies 19 whereby a predetermined pressure can be maintained between the pinch rolls as may be required by the rolling operation being performed. The hydraulic systems will include the necessary relief and control valves to insure that the pressure between the pinch rolls 18 can be quickly varied and brought to a predetermined selected contact pressure.

An explanatory illustration and description of the construction of the various parts of the stand 11, the pinch roll units 15 and 16, the piston cylinder assemblies 19, and the hydraulic systems are given in U.S. Patent No. 3,003,374 which issued to A. D. Smith, October 10, 1961. With reference to FIGURE 4 of this patent, the hydraulic lines 69 and 70 may be omitted, since the aforesaid cylinders 19 are single acting and a more simplified valve arrangement can be employed than the one shown. Also in the hydraulic system for the present invention only one pump is necessary.

Adjacent to the entry side of the pinch roll unit 15 there is provided a payoff reel 22 onto which a coil C of strip S is placed for feeding into the pinch roll unit 15. Adjacent to the delivery side of the pinch roll unit 16 there is provided a two roll driven tension bridle 23 and a tension wind-up reel 24. In rolling certain types of strips, the tension bridle unit may be bypassed and the strips brought directly to the reel 24. As will be more fully appreciated hereinafter, the operation of the tension bridle is contrary to normal practice in that it is operated to maintain the tension value between the mill and bridle substantially low and between the bridle and reel at a value to assure that a tightly wound coil is provided. Normally the bridle is employed to impose tension of a high order at the bite of the mill.

Means are provided, for example, in the form of three tensiometers 25 located in either side of the stand 11 and between the pinch roll unit 16 and the tension bridle 23 to determine and control the tension in the strip at these three areas. By means of the controls 26 of the tensiometers, the operator can adjust the pinch roll units, at the aforesaid locations. While the tension between the pinch roll units and mill will be maintained below the yield point of the strip, the tension in the bite of the mill rolls will be above the yield point due to the fact that the metal at this point is already flowing or plastic, and consequently, the tension will correct the non-flatness if any exists in the strip in the bite of the mill rolls.

The tensiometers 25 may also be employed to control automatically the motor speeds of the mill and/or pinch roll units and the pressure applied by the piston cylinder assemblies 19. Through a well-known control means the tension may be maintained at the optimum value to give the best results in accordance with the various rolling factors involved. The construction and operation of the tensiometers 25 may take many forms such as shown in U.S. Patent No. 2,223,718 which issued to W. G. Cook on December 3, 1940 and U.S. Patent No. 2,215,329 which issued to G. P. Lessmann on September 17, 1940. The electrical control and interconnections between the motors of mills, tension bridle, pinch roll units, and tensiometers may follow the teachings of well-known practice. U.S. Patent Nos. 2,715,701 and 2,715,702 which issued to R. W. Moore et al. and A. J. Winchester, Jr., on August 16, 1955 respectively, are explanatory, in part, of such practice.

In one form of practicing the present invention, the pressure in the piston cylinder assemblies 19 will be set to be sufficiently high to assure the creation of the necessary interstand tension and yet being kept as low as pos-

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sible so as to militate against a reduction being taken in the pinch roll units 15 and 16.

In the event it is required to change the tension as required by the non-flat condition of the strip, the speeds of one or more of the mill motors 28 will be changed which will result in a change in tension between the stand 11 and one or both of the pinch roll units 15 and 16. The tensiometer 25 that is affected by the change in tension will produce a signal that will be sent to the control 26. The control 26 will, in turn, produce a signal that will be sent to the delivery valve 20, thereby to change the pressure so as to maintain the aforesaid relationship, namely, maintaining the pressure high enough to create the tension yet being as low as possible to militate against any reduction being taken by the pinch roll units.

As shown in FIGURE 1, this relationship is maintained by providing a pressure transducer 25a and a servo 20a for the delivery valve 20. The transducer and servo are connected to an amplifier 20b, the amplifier also receiving a signal from the tensiometer 25 and a voltage adjustment device 20c. In operation a signal from the tensiometer 25 is received by the amplifier 20b which produces a signal to operate the delivery valve 20. Should the strength of the signal delivered to the valve 20 exceed the desired tension limitation, then the pressure transducer 25a will send a signal to the amplifier 20b to limit the signal going to the valve 20 within the permissible range. Thus, it will be appreciated in this form there is established a constant relationship between the tensioning of strip and the pressure in the bite of the rolls of the pinch roll unit. As the tension is changed to correct for flatness, the pressure between the rolls of the pinch roll is changed to maintain the relationship between tension and pressure constant.

A brief description of one manner of operating the mill arrangement of FIGURE 1 will now be given:

Once the coil C has been placed on the payoff reel 22 the strip S is fed, as indicated by the arrow, through the pinch roll unit 15, stand 11, pinch roll unit 16, guided around the rolls of the tension bridle 23 and wrapped upon the wind-up reel 24. The operator will have, in certain cases, the option of employing either or both of the pinch roll units 14 and 15 to impose the required tension upon the strip to remove the non-flatness during rolling in the stand 11. Hence, tension may be imposed on the strip on the delivery side of the stand 11 or the entry side thereof, since the entry tension as well as the delivery tension will both act on the strip at the zone of the roll bite.

While these tensions will augment the rolling pressure, it will be appreciated that due to the fact that different portions of the strip have been elongated more than others, either during rolling in the stand 11 or prior thereto, which condition caused the non-flatness of the strip, the tension will create greater reduction pressure on certain transverse portions of the strip than what exists on other portions thereof. As a result, the portions of the strip that are flat, and hence taut, will be elongated more than the non-flat portions which will decrease the elongational difference, the net result being that the strip will be flattened.

When the material entering the mill is badly out of shape, i.e., non-flat or the mill rolls are worn or improperly crowned or a combination of these and other conditions, so that the non-flatness of the strip can not be corrected by the entering or delivery tension alone, then in that event, both entry and delivery tensions may be employed.

As previously indicated, and contrary to normal practice, the tension bridle 23 and wind-up reel 24 are operated so that no appreciable tension is exerted on the strip between the tension bridle and the pinch roll unit 16, the purpose being to prevent reduction in the pinch roll unit on the one hand and yet to provide sufficient tension between the bridle and the reel 24 by using the tension bridles as a drag unit. This insures a tight, well wrapped coil.

It will be appreciated, that while in FIGURE 1 a single 4-high mill has been shown, as demonstrated in FIG-

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FIGURE 2, the present invention may also be employed in a tandem mill as well as other types of roll arrangements, i.e., 2-high, 3-high, etc., and that in place of the pinch roll units 15 and 16 conventional rolling mills may be employed, modified and operated to obtain the same result that is obtained by the pinch roll units.

To further facilitate the understanding of the operation of the mill arrangement shown in FIGURE 1, it may be well to give a typical operational example thereof.

Let it be assumed that entry tension is not needed so that the pinch roll unit 15 need not be employed. The rolls 13 and 14 of the 4-high stand 11 are 21 inches and 56 inches x 48 inches, the diameters of the rolls 18 of the pinch roll unit 16 being 36 inches, the diameter of the tension bridle 23 being 24 inches, that of the reel 24 being 16½ inches. The motors 28 of these members have horsepower ratings of 250, 2000, 1000, 200, and 250, respectively. The speed range of the mill is 1000 to 2000 f.p.m. The thickness range entering the mill is .009 to .016 inch and the strip may vary in width from 24 inches to 42 inches.

Let it be assumed further that the mill is wet rolling .016 x 40 inches wide low carbon strip to .0104 x 40 inches wide at 2000 f.p.m., wherein a reduction is only taken in the 4-high stand. By wet rolling is meant the employment of a lubricant on the working rolls and/or strip which assists in the reduction action. The pull of the strip leaving the 4-inch stand 11 is 11,400 lbs. or 25,000 lbs./sq. in. operating at 700 H.P. The pull between the pinch roll 16 and the tension bridle 23 is 416 lbs. or 1000 lbs./sq. in. operating at 25 H.P. The pull between the bridle 23 and the reel 24 is 2500 lbs. or 6000 lbs./sq. in. in operating at 150 H.P., which as previously noted will act as a drag between the reel 24 and the tension bridle 23. In returning for a moment to the tension between the stand 11 and the pinch roll unit 16, the aforesaid magnitude of 25,000 lbs./sq. in., while below the yield point in the strip proper, is above the yield point in the bite of the rolls 13 since the material under the reduction action is already plastic and flowing.

One other form of the present invention is shown in FIGURE 2. In FIGURE 2 a two-stand 4-high temper cold mill 30 is illustrated. This mill comprises two practically identical tandemly arranged mill stands 31 and 32, each having a pair of driven working rolls 33 and 34, respectively, and backing-up rolls 35.

At the entry side of the stand 31, which is indicated by the arrow, there is provided a pay-off reel 36 and on the delivery side of the stand 32, a two roll driven tension bridle 37 is provided followed by a tension reel 38. The stand 32 differs in construction from the stand 31, namely, in that piston cylinder assemblies 39 are mounted in each housing at the base thereof, which urge vertically the lower backing-up roll 35 and the lower working roll 34.

The function of the stand 32 and the auxiliary equipment are similar to that of the pinch roll units 15 and 16 so that a discussion thereof is deemed unnecessary. It will be appreciated that the present invention may find usefulness in processing equipment other than rolling mills such as in die drawing or in planetary mills having one reducing roll that cooperates with a fixed die.

In accordance with the provisions of the patent statutes, I have explained the principle and operation of my invention and have illustrated and described what I consider to represent the best embodiment thereof. However, I desire to have it understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. In a method of rolling metallic strip material wherein the strip is characterized by adjacent transverse portions elongated to different degrees longitudinally of the strip, which condition causes the portion subject to greater elongation to become non-flat, the steps comprising:

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passing the strip between a first pair of rolls to roll the strip,

passing the rolled strip between a second pair of rolls wherein the strip is forceably contacted by said rolls, controlling the contact pressure of said second pair of rolls in a manner that the reduction in thickness of the strip taken by said second pair of rolls is substantially zero,

controlling the respective speeds of said two pairs of rolls to impose upon the strip a tension that will contribute to the rolling of the strip by said first pair of rolls in a manner that the differences in elongation of said portions will be reduced and the non-flatness removed,

creating two different tension zones after the strip leaves the second pair of rolls, wherein the tension upon the strip in the first zone closest to the second pair of rolls is maintained of an order to militate against any reduction being taken by said second pair of rolls and the tension upon the strip in the second zone furthest away from the second pair of rolls is maintained of an order sufficient to cause the strip to be tightly formed into a coil, and coiling said strip after it leaves said second tension zone.

2. In a method of rolling metallic strip material wherein the strip is characterized by adjacent transverse portions elongated to different degrees longitudinally of the strip, which condition causes the portion subject to greater elongation to become non-flat the steps comprising:

passing the strip between a first pair of rolls to roll the strip,

passing the rolled strip between a second pair of rolls wherein the strip is forceably contacted by said rolls, controlling the contact pressure of said second pair of rolls in a manner that the reduction in thickness of the strip taken by said second pair of rolls is substantially zero,

operating said second pair of rolls at a speed greater than the speed of said first pair of rolls to impose upon the strip leaving the mill a tension that will contribute to the rolling of the strip by said first pair of rolls in a manner that the differences in elongation of said portions will be reduced and the non-flatness removed,

creating two different tension zones after the strip leaves the second pair of rolls, wherein the tension upon the strip in the first zone closest to the second pair of rolls is maintained of an order to militate against any reduction being taken by said second pair of rolls and the tension upon the strip in the second zone furthest away from the second pair of rolls is maintained of an order larger than the tension of the first zone and sufficient to cause the strip to be tightly formed into a coil, and coiling said strip after it leaves said second tension zone.

3. In a method of rolling according to claim 2 wherein, before the strip is passed between said first pair of rolls, the step of

passing the strip between a third pair of rolls arranged on the side of said first pair opposite said second pair, and wherein the strip is forceably contacted by said third pair of rolls,

controlling the contact pressure of said third pair of rolls in a manner that the reduction in thickness of the strip is substantially zero,

operating said third pair of rolls at a speed less than the speed of said first pair of rolls to impose upon the strip a tension as it enters said first pair of rolls that will contribute to the rolling of the strip by said first pair of rolls in a manner that the differences in elongation of said portions will be reduced.

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4. In a method according to claim 2 including the additional step of controlling the tension imposed on the strip as it leaves said second pair of rolls and the tension under which the strip is coiled.
5. In a method according to claim 2, including the additional step of maintaining the tension between said two pairs of rolls at a predetermined value.
6. In a method according to claim 2, including the additional step of correlating the contact pressure of said second pair of rolls and the tension imposed on the strip on one of the sides of said second pair of rolls and adjusting the contact pressure of said second pair of rolls to maintain the relationship so as to militate against any such reduction being taken by said second pair of rolls.
7. In an apparatus for rolling strip material wherein the strip is characterized by adjacent transverse portions elongated to different degrees longitudinally of the strip, which condition causes the portions subject to greater elongation to become non-flat,
- a first unit having a pair of rolls between which the strip is passed to perform a rolling operation,
- a second unit having a pair of rolls between which the strip is passed,
- means for bringing the rolls of said second unit into forceable contact with the strip,
- means for controlling the contact pressure of said pair of rolls of said second unit in a manner that little or no reduction in thickness of the strip is taken by said rolls,
- means for controlling the respective speeds of said two pairs of rolls to impose upon the strip a tension that will contribute to the rolling of the strip in a manner that the differences in elongation of said portions will be reduced and the non-flatness removed,
- means for creating a first and a second tension zone after the strip leaves the second pair of rolls, the tension upon the strip in said first tension zone being of a low magnitude in comparison with the magnitude of the tension imposed upon the strip between said two pairs of rolls and the tension upon the strip in said second zone being sufficient to assure that a tightly formed coil will be obtained, and means for coiling said strip in said second zone.
8. In an apparatus for rolling strip according to claim 7, a third unit having a pair of rolls arranged on the side of the first pair opposite said second pair is arranged, means for controlling the contact pressures of said pair of rolls of said third unit in a manner that lit-

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- tle or no reduction in thickness of the strip is taken by said rolls,
- means for controlling the respective speed of said third pair of rolls relative to said first pair of rolls to impose upon the strip a tension that will contribute to the rolling of the strip in a manner that the differences in elongation of the portion will be reduced.
9. In an apparatus for rolling strip according to claim 7,
- a tension bridle arranged on the delivery side of said second pair of rolls for receiving and imposing tension on the strip,
- means for operating the bridle in a manner that the tension on the strip between the bridle and second pair of rolls will be substantially small in comparison with the tension on the strip between said two pair of rolls, and the tension on the strip between said bridle and said means for coiling the strip will be sufficient to form tightly wound coils.
10. In an apparatus for rolling strip according to claim 7 including hydraulic means for urging one of said second pair of rolls toward the other roll, and means for controlling the pressure of said hydraulic means to control the contact pressure of said rolls.
11. In an apparatus for rolling strip according to claim 7 including means for maintaining the tension between said two pairs of rolls at a predetermined value.
12. In an apparatus for rolling strip according to claim 7 including means for correlating the means for controlling the contact pressure and the means for imposing and controlling the strip tension.
13. In a method according to claim 2, including the additional steps of:
- establishing a constant relationship between the tension of the first and second pairs of rolls, and changing the tension between said first and second pairs of rolls to correct for non-flatness in the strip in a manner that said relationship is maintained substantially constant.

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