

Feb. 28, 1967

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3,306,091

ROLLING MILL

Filed Jan. 16, 1964

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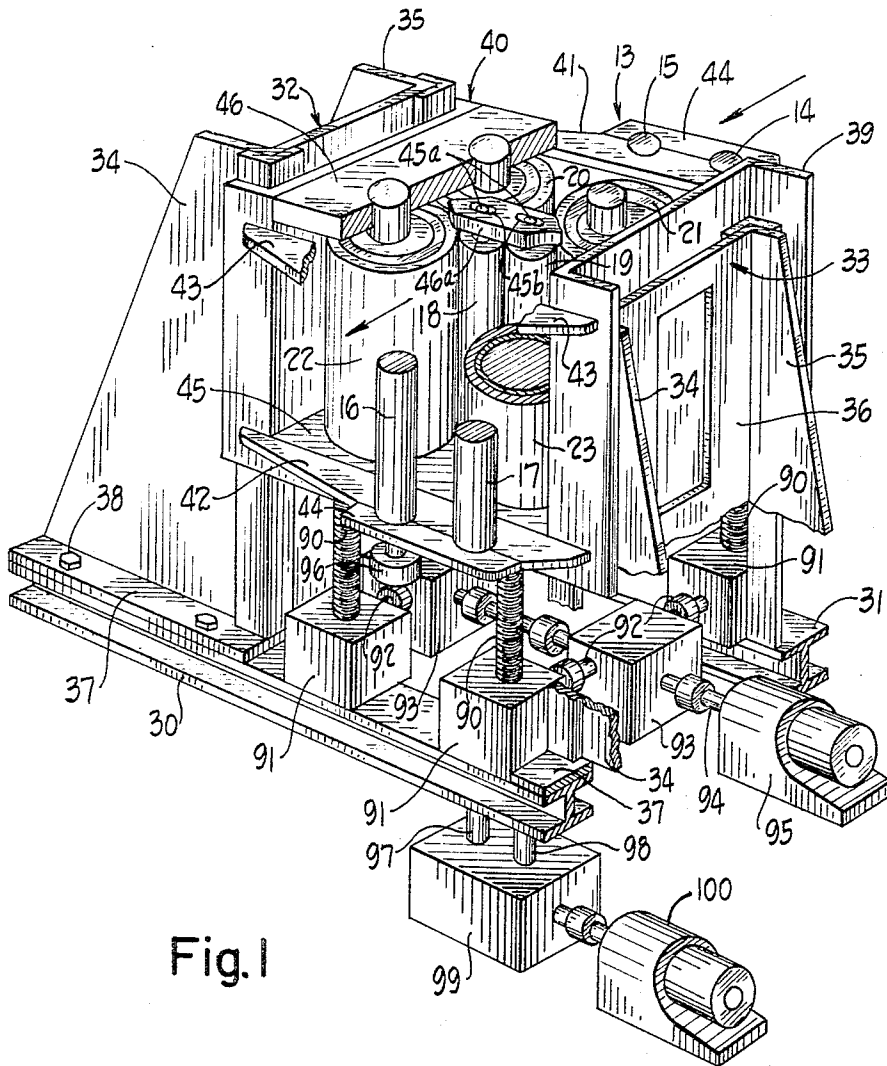


Fig. 1

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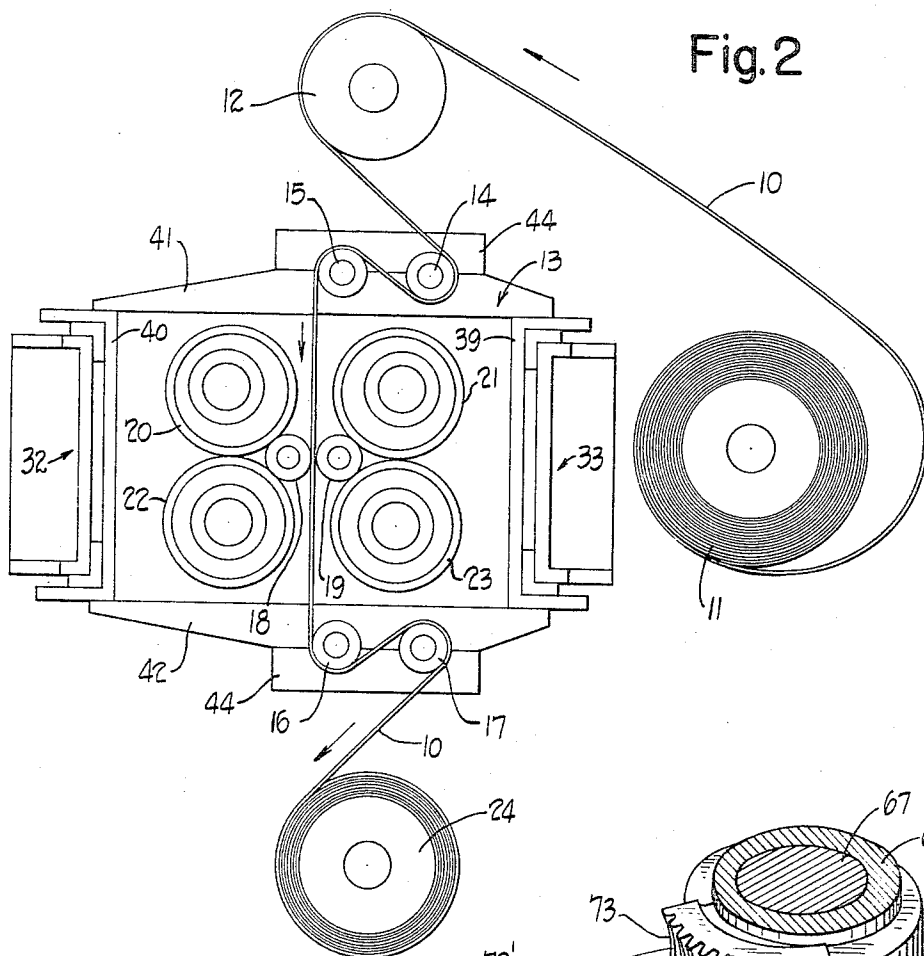
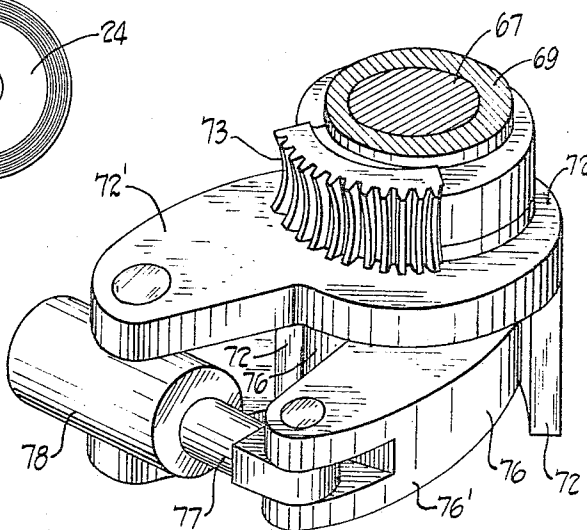


Fig. 7



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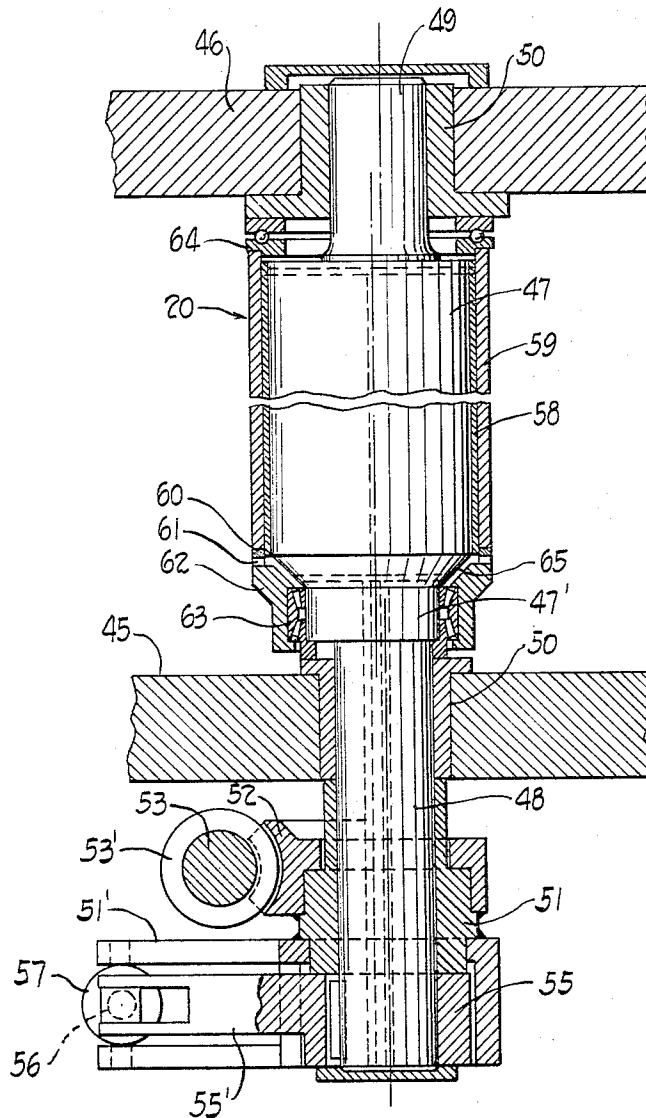


Fig. 3

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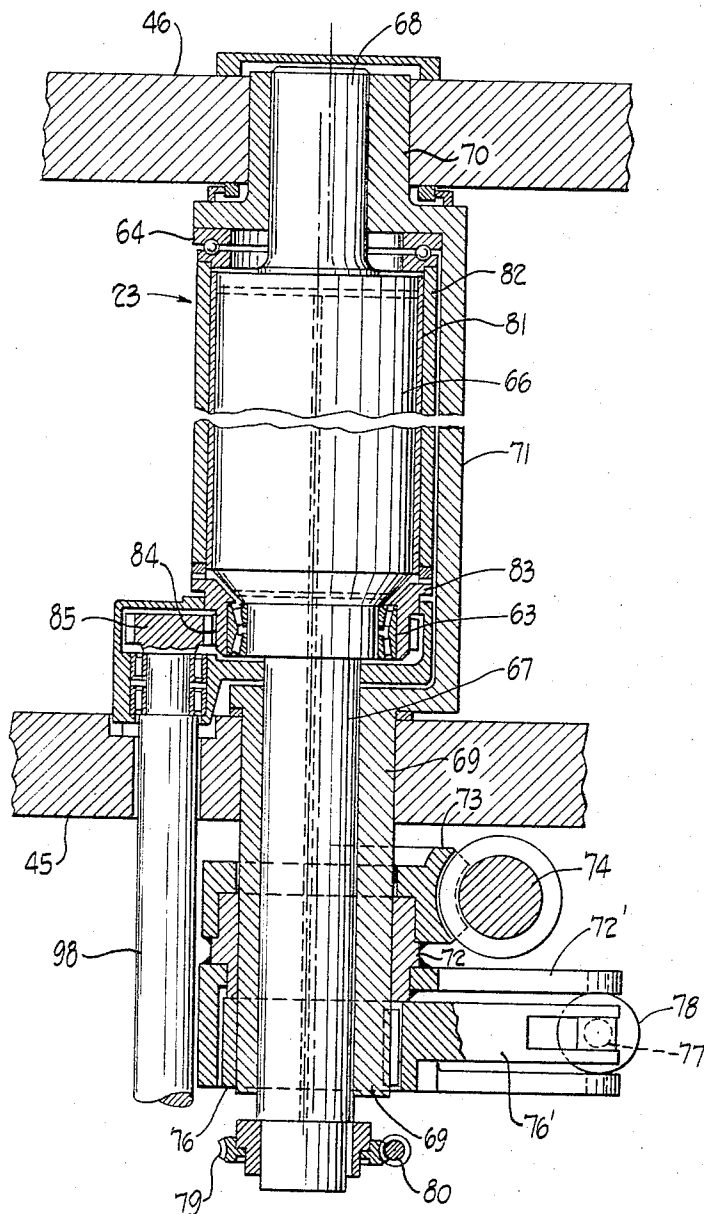


Fig. 4

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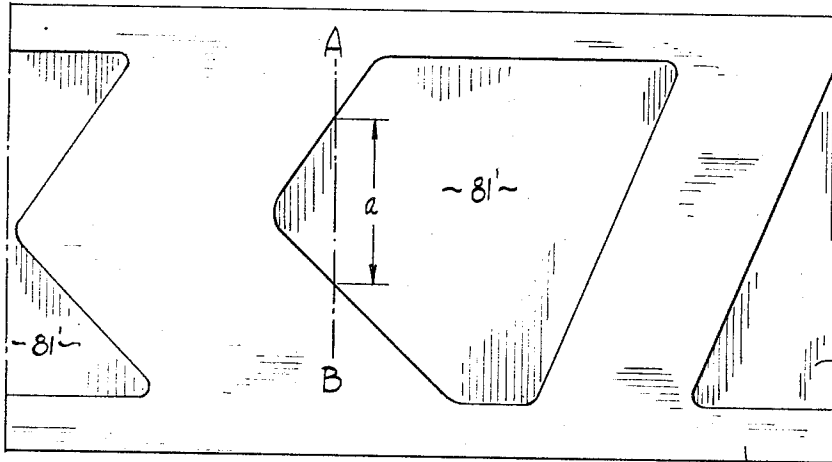


Fig. 6

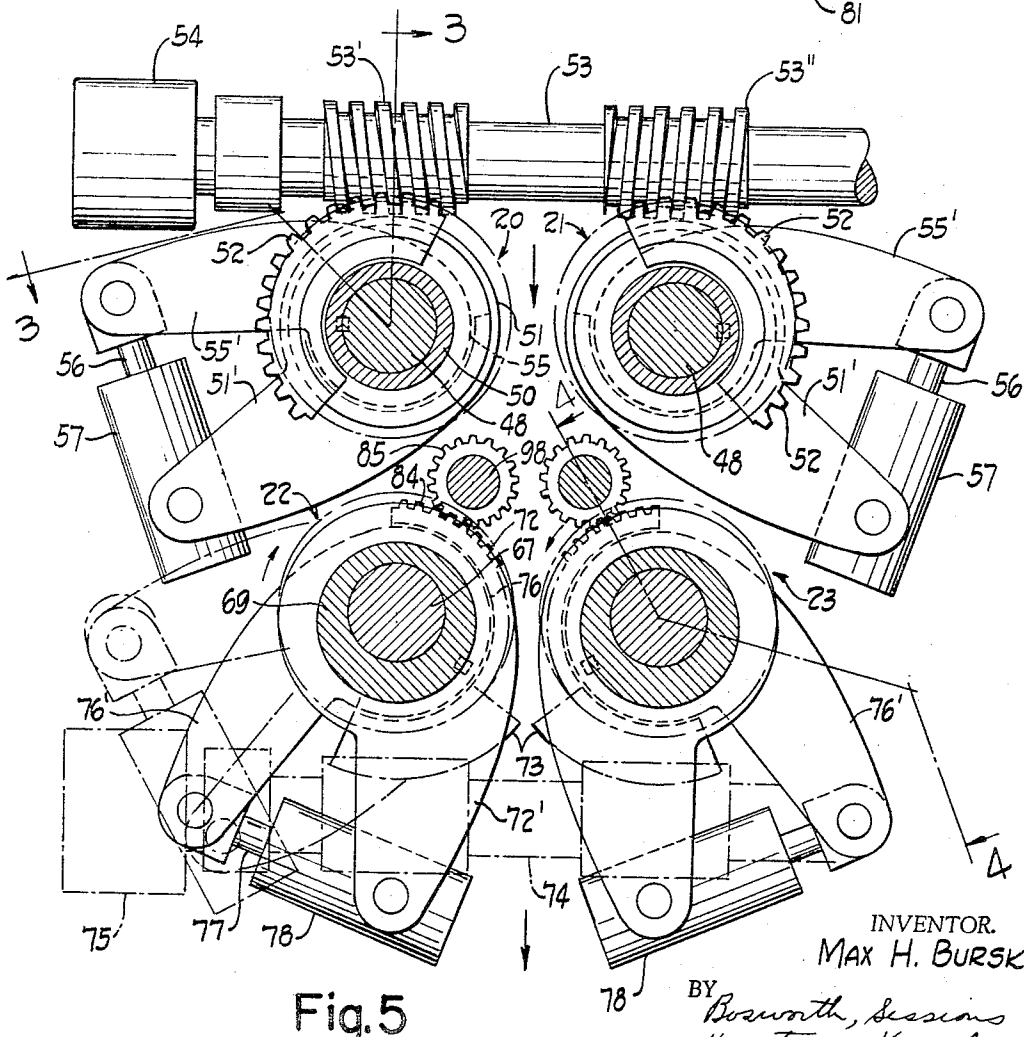


Fig. 5

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3,306,091

ROLLING MILL

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14 Claims. (Cl. 72-240)

This invention relates to a rolling mill for treating, especially temper-rolling or skin-passing, metal strip. The mill may likewise be used for certain cold reductions of metal strip.

A known process permits the opening of a tight coil to a so-called open or loose coil with regular spacing between individual laps of the coil. This open or loose coil is formed by inserting a nylon cord, twisted metal wire or some other spacer between the laps. The nylon cord is removed prior to annealing, whereas the metallic separator may be left in the coil. According to this process, the opened coil of metal strip is lifted by means of a special magnet or a suitable crane and brought into an annealing furnace. The spaces between the individual laps of the metal strip enable the gases circulating in the furnace to come into contact with the whole surface of the coil. After treatment in the furnace and subsequent cooling of the loose coil, the latter is rewound into a tight coil.

It is also a well known procedure in the treating of annealed coils to convey the coil to a rolling mill where the strip is passed through the mill and is subjected to a very slight reduction in order to cause a hardening effect and to improve the surface of the metal strip.

An object of the present invention is to provide improved apparatus for carrying out such slight reduction.

The rolling mill according to the invention is characterized by the provision of flexible work rolls and an adjustable device for supporting said work rolls whereby the profile of the roll gap may readily be changed. The profile of the roll gap may thus either be made to correspond to the profile of the metal strip to give a uniform skin pass over the full width of the strip, or may be given a form which results in a variable rolling pressure being applied over the width of the strip to correct the contour thereof.

As a result the rolling mill according to the invention may be used to change the profile of the metal strip i.e. to correct deviations from the desired profile of the strip.

The drawings show a diagrammatic illustration of an example of my improved mill particularly adapted for carrying out the process. They show in:

FIG. 1 a mill diagrammatically illustrated, and partly in section,

FIG. 2 a plan view of the mill of FIG. 1,

FIG. 3 a longitudinal section of one of the entering back-up rolls along line III-III of FIG. 5,

FIG. 4 a longitudinal section of one of the exit back-up rolls along line IV-IV of FIG. 5,

FIG. 5 a horizontal cross-section of the back-up rolls,

FIG. 6 a developed roll bushing, and

FIG. 7 a perspective view of the hydraulic vernier adjusting device for the exit back-up rolls.

According to FIG. 2 a metal strip 10 runs from a "loose coil" 11 to a rubber covered tension roller 12. The strip is passed around this tension roller 12 and enters the rolling mill 13 for processing. This rolling mill 13 is provided on the entering side with two tension rolls 14 and 15 and on the exit side with two further tension rolls 16 and 17. Between these four tension rolls 14 to 17 the metal strip 10 passes between two vertical axis flexible work rolls 18 and 19 which are supported by four vertical axis back-up rolls 20 to 23. The metal strip 10 is rolled into a tight coil 24 after leaving the rolling mill 13.

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The arrangement of the back-up rolls 20-23 is such that they are adjustable with regard to the work rolls 18 and 19 by means hereinafter described.

Under certain conditions it may be desirable to skin-pass the metal strip 10 in which event only two rolls with relatively large diameter may be used in order to obtain a better surface. It is possible in such a case to utilize the two exit back-up rolls 22 and 23 as work rolls.

According to FIGURE 1, two U-shaped guides 32 and 33 are arranged on two beams 30 and 31 which form a base. These two guides 32 and 33 each comprises three side walls 34, 35, 36 and a base plate 37 which are welded together and are firmly connected with the base beams 30 and 31 by screws 38. The actual casing or housing of the rolling mill 13 is guided between these guides 32, 33 so as to allow vertical adjustment thereof. This casing comprises two U-shaped side supports 39 and 40, which are held together by four connecting bars, of which only two, 41 and 42, are completely visible in FIGURE 1. The third bar 43 has been partially omitted for the sake of clarity, whereas the fourth connecting bar is not shown. These four connecting bars serve to support the four tension rolls 14 to 17. To facilitate the mounting and removal of these tension rolls 14 to 17, separate bearing covers 44 (see FIG. 1) are removably secured to the connecting bars 41 to 43.

At the upper and lower ends of the two side supports 39 and 40 two heavy yoke plates 45 and 46 are fixed and serve to support the four back-up rolls 20 to 23. The lower-most of these two yoke plates 45 and 46, which are made of high strength steel, is secured firmly to the side supports 39 and 40, whilst the upper yoke plate 46 is removable in order to facilitate replacement of the back-up rolls 20 to 23. For the sake of clarity the upper yoke plate 46 is not drawn completely in FIGURE 1.

According to FIGURE 3 (in which only the entering back-up roll 20 is shown), each of the entering back-up rolls 20 and 21 on the strip entrance side of the mill consists of similar parts, each having a shaft portion 47 and eccentric trunnions 48 and 49 which extend from the opposite ends of the shaft 47 and are mounted in bearing bushings 50 in the yoke plates 45 and 46. Toothed segments 52 are fixed to sleeves 51 which are rotatably mounted on the lower trunnions 48. Both toothed segments 52 engage with a worm shaft 53 (see FIG. 5) which is provided with a right-hand thread 53' at one end and a left-hand thread 53'' at the other end and is coupled to an electric motor 54. Furthermore, lower sleeves 55 are keyed to the trunnions 48 and piston rods 56 are connected to arms 55' carried by the lower sleeves 55, the pistons on the piston rods 56 being arranged for movement in the hydraulic cylinders 57 which are pivotally mounted on the arms 51' carried by upper sleeves 51. The trunnions 48 of back-up rolls 20 and 21 are thus coupled with the worm shaft 53 by means of the hydraulic cylinders 57. By operating the electric motor 54 the eccentrically mounted shafts 47 are turned around the axes of the trunnions 48 and 49 whereby the space between the two entering back-up rolls 20 and 21 is varied. As the rolls 20 and 21 are disposed to engage the work rolls 18 and 19 respectively on the strip entering side of the roll pass between the work rolls 18 and 19 the roll gap between the work rolls 18 and 19 will be varied when the back-up rolls 20 and 21 are adjusted toward or away from each other.

After the distance between the back-up rolls has been approximately adjusted by rotating the trunnions 48 by means of the worm shaft 53, the motor 54 is stopped and the hydraulic cylinders 57 and piston rods 56 (which are connected to arms 55' which are carried by lower sleeves 55) are operated so as to rotate the lower sleeves 55 rela-

tive to the upper sleeves 51, which are now held stationary by the toothed segments 52. A fine adjustment of the location of the axes of the back-up rolls is thus obtained. The hydraulic pressure that is exerted by the hydraulic cylinders 57 is controlled by means of suitable adjustable pressure relief valves or the like (not shown) to obtain the exact desired reduction of the strip being rolled. By means of these hydraulic cylinder arrangements variations in strip thickness are automatically compensated for, thus providing the same reduction from end to end of the strip.

In the rolling zone between the two yoke plates 45 and 46, a roll bushing 58 is keyed onto the shaft 47. An outer roll sleeve 59 is rotatably mounted on this roll bushing. To facilitate replacement, this roll sleeve 59 is provided at its lower end with a ring portion 60 (see FIGURE 3) having a toothed bottom rim 61 which meshes with a corresponding toothed rim on a ring 62 and which is supported at its lower end on an anti-friction bearing 63 mounted on the reduced bottom end portion 47' of the shaft 47. The roll sleeve 59 is also supported by means of a thrust bearing 64 at its upper end.

Oil for the lubrication of the roll sleeve 59 and for the dissipation of heat is conducted upwards through suitable passages in the shaft 47, arrives at the outside thereof by means of radial boreholes, and flows downwards between roll bushing 58 and roll sleeve 59 into the space 65 from where it flows back into the shaft end portion 47' and is then conducted downwardly through trunnion 48 to suitable cooling and circulating means (not shown).

The two adjustable rolls 22 and 23 are identical and are arranged on the exit side of the roll pass between work rolls 18 and 19. These adjustable rolls 22 and 23 serve as exit back-up rolls for the work rolls 18 and 19. Only roll 23 is shown in FIGURE 4 and it differs from the above described entering back-up rolls 20 and 21 in the manner described below.

Referring to FIGURE 4 which illustrates the adjustable back-up roll 23, on both ends of the vertical axis non-rotating shaft portion 66 trunnions 67 and 68 are arranged concentrically with the shaft 66. These trunnions are mounted rotatably in eccentric bushings 69 and 70 which in turn are rotatably mounted in the yoke plates 45 and 46. The eccentric bushings 69 and 70 are also connected by a yoke 71 which extends vertically therebetween. The lower eccentric bushing 69 extends downwardly through the yoke-plate 45 as is clearly seen in FIGURE 4.

An upper sleeve 72 is rotatably mounted on the eccentric bushing 69 and a toothed segment 73 is keyed thereto. The toothed segments 73 of both back-up rolls 22 and 23 are engaged by a worm shaft 74 (see FIG. 5) which has a left-hand thread at one end and a right-hand thread at the other. The worm shaft 74 is connected to an electric drive motor 75. A lower sleeve 76 is keyed to the eccentric bushing 69 and a piston rod 77 is connected to an arm 76' which is integral with and projects from lower sleeve 76. The piston on piston rod 77 is arranged for movement in a cylinder 78 which is pivotally mounted on the arm 72' is integral with and projects from the upper sleeve 72. The arrangement is such that the eccentric bushing 69 is coupled through the piston rod 77 and the cylinder 78 with the worm shaft 74.

By rotating the eccentric bushings 69 and 70 of back-up rolls 22 and 23 in opposite directions the distance between the exit back-up rolls 22 and 23 can be altered so as to compensate for wear and to adjust these rolls when they are used for rolling. An approximate adjustment is made by means of the worm shaft 74 which actuates the toothed segments 73 while the fine adjustment is carried out by means of the cylinders 78 in the manner described above in connection with back-up rolls 21 and 22.

A worm wheel 79 is fixed for rotation on the lower end of trunnion 67, which extends through the yoke plate 45 and the eccentric bushing 69. The worm wheels 79 of both back-up rolls 22 and 23 engage with a worm shaft

80, the worm shaft 80 being coupled with an electric motor not shown.

A non-rotating recessed roll bushing 81 is fixed on the shaft portion 66 and is provided with shallow recesses 81' on its outer surface for purposes to be later described. FIGURE 6 shows a development of this roll bushing 81. A flexible tubular roll sleeve 82 is mounted for rotation on the roll bushing 81 and is supported by bearings 63 and 64 in the same manner as previously described in connection with back-up roll 20.

The shaft portions 66 of exit back-up rolls 22 and 23, and the roll bushings 81 fixed thereto, are angularly adjustable in opposite directions by means of the worm shaft 80 and worm wheels 79 whereby the angular position of the recesses 81' in the roll bushings 81 can be altered with respect to the lines of contact between the work rolls 18 and 19 and the exit back-up rolls 22 and 23. At the points where the recesses are located, the comparatively thin and flexible roll sleeves 81 may deflect whereby the flexible work rolls 18 and 19 may deflect correspondingly. The operator of the rolling mill can control the shape of the roll pass or profile by rotating the recessed bushings 81 so as to vary the relative position of the irregularly shaped recesses 81' with regard to the lines of contact between the back-up rolls 22 and 23 and the work rolls 18 and 19. It will be noted from FIGURE 6 that some of the edges of the recessed portions 81' are inclined to the axis of the bushing 81 and roll sleeve 82 thus making possible a wide variation in the location and length of the unsupported portions of sleeve 82. Should a local variation, for example an increase in thickness in the median section of the strip, occur the roll bushings 81 may be rotated so as to present a recessed portion 81' at said section. In this way, the work rolls 18 and 19 may be deformed during the rolling operation by a local increase in the thickness of the strip, said work rolls 18 and 19 being supported by contact with the back-up rolls 22 and 23 with the exception of the region in which the recess 81' is located which region is adjusted to be in vertical alignment with the area of increased strip thickness.

More specifically, referring to FIGURE 6, if the center portion of the width of the strip being rolled is thicker than the top and bottom portions of the strip, as suggested in the above noted example of local variations, the shaft portions 66 of back-up rolls 22 and 23, and the recessed roll bushings 81 fixed thereto, would be rotated by means of the worm shaft 80 and the worm wheels 79 until the portions of the bushings 81 indicated by line A-B in FIGURE 6 would lie at the lines of contact between the back-up rolls 22 and 23 and the work rolls 18 and 19.

With recessed bushings 81 so adjusted the work rolls 18 and 19 will be fully supported on the exit side of the roll pass by contact with the back-up roll sleeves 82 except for the portions of the contact lines, indicated at *a* in FIGURE 6, where the recesses 81' are disposed. These recesses are shallow, for example .002" and .005", but are sufficient to permit the roll sleeves 82 to deflect inwardly at this portion of the lines of contact between the roll sleeves 82 and the work rolls, with corresponding outward deflection of the work rolls 18 and 19, to accommodate for the increased thickness of the strip at this center portion.

It will be observed that by positioning the recessed bushings 81 so that correct portions of the recesses 81' are disposed at the lines of contact between the back-up rolls and the work rolls, accommodation may be made in the form of the roll pass for strip which is thick on the top edge, thick at the bottom edge, thick at the top and bottom edges, etc., etc. By properly adjusting the recessed bushings 81 the work rolls 18 and 18 may be made to exert equal pressure across the entire width of the strip being rolled or to exert greater pressure at certain areas than at other areas in order to correct the strip profile or

cross-section. Furthermore, the worm shaft 80 may be actuated in response to continuously reading strip thickness gauges (not shown), disposed to indicate changes in the strip profile or cross-sectional shape, so that the profile of the roll pass between the work rolls 18 and 19 will be automatically adjusted to maintain the desired strip cross-section.

Lubrication of the roll sleeves 82 which rotate on the recessed bushings 81 is similar to that previously described in connection with back-up rolls 20 and 21 and, in accordance with well known principles, an oil film of uniform thickness will be maintained at all times between the sleeves 82 and bushings 81.

The ring 83 which supports the roll sleeve 82 and is similar to ring 62, has a gear rim 84 on its outer periphery, which engages the pinion 85 secured to the driving shaft 98. This driving shaft is coupled by suitable gears to an electric motor 100 (see FIGURE 1).

Both work rolls 18 and 19 are supported solely by bearings 45a arranged at their upper ends. These bearings are mounted in a separate support housing 46a which fits into yoke plate 46. The bearings 45a are supported in housing 46a for limited movement toward and away from each other (as by slots 45b) and consequently rolls 18 and 19 may also have limited movement toward and away from each other. As the housing 46a and the work rolls 18 and 19 form a unit it is possible to change one set of work rolls by lifting the housing 46a and rolls 18 and 19 with a crane and replacing them with a new unit of rolls, bearings and support housing.

To raise and lower the yoke plates 45 and 46, which are secured to the side supports 39 and 40, together with the work and back-up rolls 18 to 23, which are mounted between them, and to also raise and lower the tension rolls 14 to 17, four screw jacks 91 (FIG. 1) with spindles 90 are mounted on the base beams 30 and 31. These screw jacks 91 are connected by clutches and shafts 92 with two gear boxes 93 which are connected by a shaft 94 to a driving motor 95. The lower yoke plate 45 rests on these four spindles 90 which can be lifted and lowered by the screw jacks 91.

Each of the four tension rolls 14 to 17 is driven by a separate motor. In FIGURE 1 only one of these motors, 96, for the tension roll 16, is illustrated for the sake of clarity. These motors 96, which are mounted on the lower side of the connecting bar 42, serve to drive rolls 14 to 17 at such speeds as will give the proper tension to the metal strip 10 being rolled by acting on the strip as it enters and leaves the rolling mill 13.

The mode of operation of the described installation is as follows:

A loose or open coil 11 (FIG. 2), which has been removed from the annealing furnace, is directed around the tension drum 12 into the rolling mill 13. The lower edge of the metal strip 10 is always situated at the same height, as all the coils coming from the annealing furnace are brought to the same wind-off turntable. Depending on the width of the metal strip 10, the housing 39, 40, 45, 46, together with the four back-up rolls 20 to 23, the two work rolls 18 and 19, and the four tension rolls 14 to 17, can be so regulated in its vertical position that the strip 10 is always located exactly in the middle of the mentioned rolls. For this purpose the four screw jacks 91 are driven by motor 95. Depending on the direction of rotation of the motor 95, the screw jacks 91 either raise or lower the spindles 90 whereby the lower yoke plate 45, which rests on the spindles 90, is likewise raised or lowered and therewith the whole housing, until the work rolls 18 and 19 take up the desired position in relation to the strip 10. It can be seen in FIGURE 2 that the strip 10 is directed around the two tension rolls 14 and 15 on the entrance side of the rolling mill, passes between the two work rolls 18 and 19 and is finally directed around the two tension rolls 16 and 17 on the exit side of the rolling

mill. The strip 10 leaving the rolling mill 13 is rolled into a tight coil 24 on a suitable turntable.

The feed of the metal strip 10 is effected by the main driving motor 100, which drives both shafts 97 and 98 through gear box 99 (see FIGURE 1). The shafts 97 and 98 drive the roll sleeves 82 of the two exit back-up rolls 22 and 23 through gears 84 and 85 as previously described. It will be understood that the drive means could also be made so that the driving shafts 97, 98 are coupled directly with the work rolls 18 and 19. In order to give the proper tension to the strip while it is being rolled, the tension rolls 14 to 17 are driven at suitable speed by means of their respective motors 96.

The hydraulic vernier cylinders 57 and 78 of the back-up rolls 20-23 are connected to a high pressure fluid pump, a control valve (not shown) being preferably provided which allows the work rolls 18 and 19 to yield in case variations arise in the thickness of the metal strip.

By means of the adjustable exit back-up roll assemblies 22 and 23 the desired effective profile or cross sectional form of the roll pass between the work rolls 18 and 19 may be obtained. Thus, by angularly adjusting the recessed roll bushings 81 about their axes, the axial position of the portions of the flexible roll sleeves 82 which are directly supported by the outer surface portions of the recessed roll bushings 81, and of the portions of sleeves 82 not so supported and which may therefore flex in a direction away from the work roll with which they engage, may be varied. This control of the location of the areas where the flexible roll sleeves 82 of back-up rolls 22 and 23 may flex into the recessed portions 81' of the roll bushings 81, with corresponding flexing when the mill is operating, of the flexible work rolls 18 and 19 which are engaged by the outer surfaces of rolls 22 and 23, enables the mill to be readily adjusted, even while operating, either to accommodate or to modify the cross-sectional form or profile of the strip being rolled.

By incorporating my vertical rolling mill of the described compact type into the open coil winding installation, the metal strip to be treated can be rolled to the required thickness and/or given the desired temper simultaneously with the tight recoiling operation. By combining the two operations production costs are lowered and work time and labor are reduced. For these reasons the herein described tempering process with open coils competes favorably with other tempering processes.

Although one form of my improved rolling mill has been illustrated and described herein in considerable detail, it will be understood that variations and modifications may be made in the form and arrangement of the parts and elements making up my apparatus without departing from the spirit of my invention. I do not, therefore, wish to be limited to the specific embodiment of my invention herein shown and described by claim as my invention all embodiments thereof coming within the scope of the appended claims.

I claim:

1. In a rolling mill, a rotatably supported flexible work roll, a rotatably supported back-up roll disposed with its axis parallel to the axis of said work roll, said back-up roll including a flexible rotatable roll sleeve the outer surface of which is in engagement with said work roll and adjustable means for selectively supporting portions of said roll sleeve against flexing while permitting flexing of other portions of said roll sleeve.

2. In a rolling mill, a frame structure, a flexible work roll rotatably supported by said frame structure, a back-up roll rotatably supported by said frame structure with its axis parallel to the axis of said work roll, said back-up roll including a flexible rotatable roll sleeve the outer surface of which is in engagement with said work roll and adjustable means for selectively supporting portions of said flexible roll sleeve against flexing in a direction away from said work roll while permitting such flexing of other portions of said roll sleeve.

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3. In a rolling mill, a frame structure, a flexible work roll rotatably supported by said frame structure, a back-up roll assembly rotatably supported by said frame structure with its axis parallel to the axis of said work roll, said back-up roll assembly including a flexible rotatable roll sleeve the outer surface of which is in engagement with said work roll, an adjustable recessed roll bushing adapted selectively to support portions of said flexible roll sleeve against flexing in a direction away from said work roll while permitting such flexing of other portions of said roll sleeve, and means for angularly adjusting said roll bushing whereby the areas of said roll sleeve supported against flexing and the areas thereof where flexing is permitted may be varied.

4. In a rolling mill, a pair of work rolls rotatably supported with their axes parallel and disposed to form a roll pass for strip metal therebetween; and a pair of back-up rolls supported respectively in backing up engagement with said work rolls; one of said work rolls being flexible and the one of said back-up rolls in engagement therewith being adjustable and including a non-rotating recessed roll bushing supported with its axis parallel to the axes of said work rolls, means for angularly adjusting said recessed roll bushing about its said axis, and a flexible tubular roll sleeve rotatably supported on said recessed roll bushing and adapted to engage and back-up said one of said work rolls, said recessed roll bushing having an outer surface portion adapted to support said roll sleeve against flexing and a portion recessed from said outer surface and permitting flexing of said roll sleeve, said means for angularly adjusting said recessed roll bushing being adapted to vary the axial location of the portion of said roll sleeve supported against flexing by said outer surface portion of said recessed roll bushing and thus to control the flexing of the adjacent work roll during operation of the mill.

5. A rolling mill as described in claim 4 in which both of the work rolls are flexible and both of the back-up rolls are adjustable and include the elements set forth in claim 4.

6. A rolling mill as described in claim 4 including means for continuously measuring the thickness of the strip being rolled at a plurality of points across its width, and means responsive to said thickness measuring means for angularly adjusting said recessed roll bushing whereby changes in strip thickness may be corrected or accommodated by said flexible work rolls.

7. In a rolling mill, a frame structure; a pair of flexible work rolls rotatably supported by said frame structure with their axes parallel and disposed to form a roll pass for strip metal therebetween; and a pair of back-up rolls supported by said frame structure respectively in backing up engagement with said work rolls; one of said back-up rolls including a non-rotating recessed roll bushing, means for supporting said recessed roll bushing on said frame structure with its axis parallel to the axes of said work rolls, means for angularly adjusting said recessed roll bushing about its said axis, and a flexible tubular roll sleeve rotatably supported on said recessed roll bushing and adapted to engage and back-up one of said work rolls, said recessed roll bushing having an outer surface portion and a portion recessed from said outer surface and having one edge inclined to said axis of said recessed roll bushing, said means for angularly adjusting said recessed roll bushing being adapted to vary the axial position of the portion of said roll sleeve which is supported by said outer surface portion of said recessed roll bushing and thus to control the flexing of said roll sleeve and the work roll which it engages.

8. A rolling mill as described in claim 7 in which both of the back-up rolls are adjustable and include the elements set forth in claim 7.

9. In a rolling mill, a roll including a flexible roll

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sleeve, a non-rotating recessed roll bushing, said flexible roll sleeve being rotatably supported on said recessed roll bushing, said recessed roll bushing having an outer surface portion adapted to support said roll sleeve and a recessed portion recessed radially inwardly from said outer surface portion; support means for said recessed roll bushing; and means for angularly adjusting the position of said recessed portion of said roll bushing relative to said support means.

10. A rolling mill roll as described in claim 9 wherein one edge of said recessed portion of said roll bushing is inclined to the roll axis.

11. In a rolling mill for rolling strip metal, a frame structure; a pair of flexible work rolls supported by said frame structure with their axes vertical and adapted to have limited movement toward and away from each other whereby the width of the roll pass therebetween may be varied; a pair of entering back-up rolls mounted on said frame with their axes vertical and disposed respectively to engage and back-up said work rolls on the strip entering side of said roll pass; means for moving said entering back-up rolls toward and away from said roll pass whereby the width thereof may be varied; a pair of exit back-up rolls mounted on said frame with their axes vertical and disposed respectively to engage and back-up said work rolls on the strip exit side of said roll pass; and means for moving said exit back-up rolls toward and away from said roll pass; the back-up rolls of one of said pairs each including a non-rotating shaft portion, a non-rotating recessed roll bushing secured on said shaft portion for angular adjustment therewith independently of movement of said one of said pairs of back-up rolls toward or away from said roll pass and having a recessed portion formed in its outer surface, a flexible roll sleeve rotatably supported on said recessed roll bushing, and means for angularly adjusting said non-rotating shaft portion and said recessed roll bushing whereby the portion of said flexible roll sleeve directly supported on the outer surface of said recessed roll bushing and the portion of said roll sleeve overlying a recessed portion of said roll bushing may be varied; said flexible roll sleeves and said flexible work rolls being adapted to flex where said roll sleeves overlie said recessed portions of said roll bushings whereby the profile of said roll pass when the mill is operating will correspond to the angularly adjusted positions of said recessed roll bushings.

12. In a rolling mill for rolling strip metal, a frame structure; a pair of flexible work rolls supported by a sub-frame structure and adapted to have limited movement toward and away from each other whereby the width of the roll pass therebetween may be varied; said work rolls and sub-frame structure being supported by said frame structure with the axes of said work rolls vertical and being removable from said frame structure as a unit; a pair of entering back-up rolls mounted on said frame with their axes vertical and disposed respectively to engage and back-up said work rolls on the strip entering side of said roll pass; means for simultaneously moving said entering back-up rolls toward and away from said roll pass whereby the width thereof may be varied; a pair of exit back-up rolls mounted on said frame with their axes vertical and disposed respectively to engage and back-up said work rolls on the strip exit side of said roll pass; and means for simultaneously moving said exit back-up rolls toward and away from said roll pass; said exit back-up rolls each including a non-rotating shaft portion, a non-rotating recessed roll bushing secured on said shaft portion for angular adjustment therewith independently of movement of said exit back-up rolls toward or away from said roll pass and having a recessed portion formed in its outer surface, said recessed portion having one edge inclined to the axis of its exit back-up roll, a flexible roll sleeve rotatably supported on said recessed roll

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bushing, and means for angularly adjusting said non-rotating shaft portion and said recessed roll bushing whereby the portion of said flexible roll sleeve directly supported on the outer surface of said recessed roll bushing and the portion of said roll sleeve overlying a recessed portion of said roll bushing may be varied, said flexible roll sleeves and said flexible work rolls being adapted to flex where said roll sleeves overlie said recessed portions of said roll bushings whereby the profile of said roll pass will correspond to the angularly adjusted positions of said recessed roll bushings.

13. A rolling mill for rolling strip metal including a frame structure, a pair of flexible work rolls rotatably supported on said frame structure with their axes parallel and spaced to form a roll pass therebetween, a pair of flexible back-up rolls including outer flexible roll sleeves and adjustable means for supporting portions of said flexible roll sleeves while other portions are permitted to deflect inwardly, said adjustable means being adapted to vary the portions of said back-up roll sleeves that are supported and that are permitted to flex inwardly on the lines of engagement of said sleeves with said work rolls.

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14. Apparatus for treating strip metal in coils as described in claim 13 in which one of said rolls includes a flexible roll sleeve and an adjustable recessed roll bushing on which said roll sleeve is rotatably supported, said roll bushing being adapted selectively to support portions of said flexible roll sleeve against flexing in a direction away from the strip being rolled while permitting such flexing of other portions of said roll sleeve, and means for angularly adjusting the position of said roll bushing whereby the areas of said roll sleeve supported against flexing may be varied.

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