Feb. 26, 1963 W. K. J. PEARSON 3,078,747

MANUFACTURE OF METAL SHEET OR STRIP

Filed Sept. 15, 1958 3 Sheets-Sheet 1

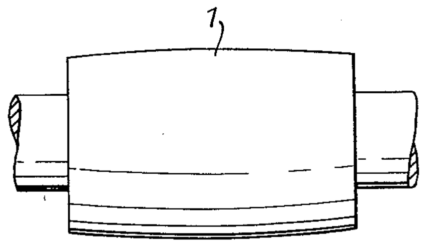

FIG.1

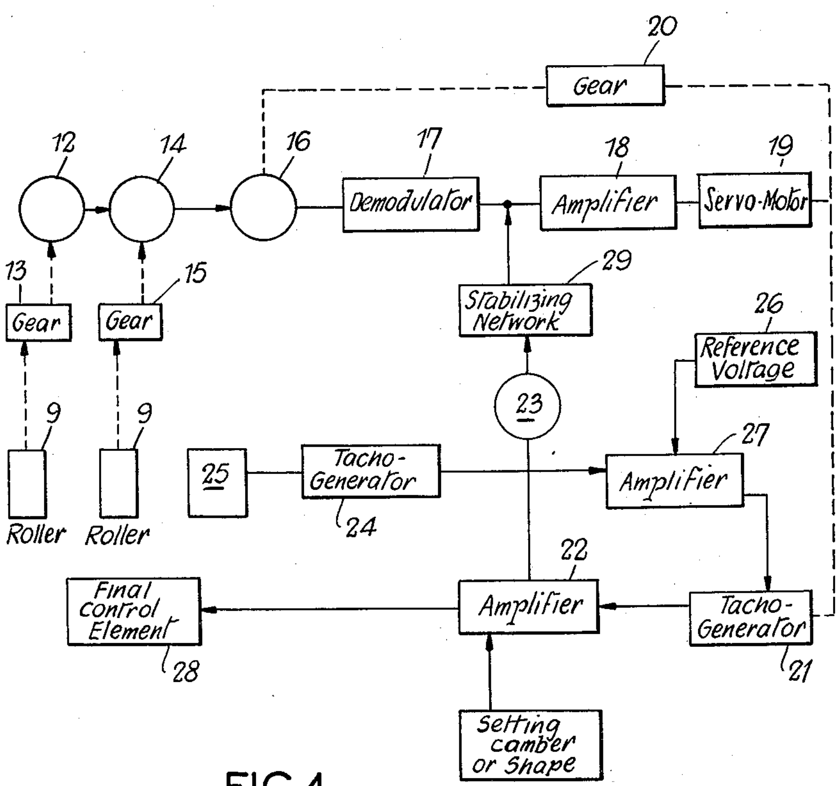

FIG.4

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FIG.2

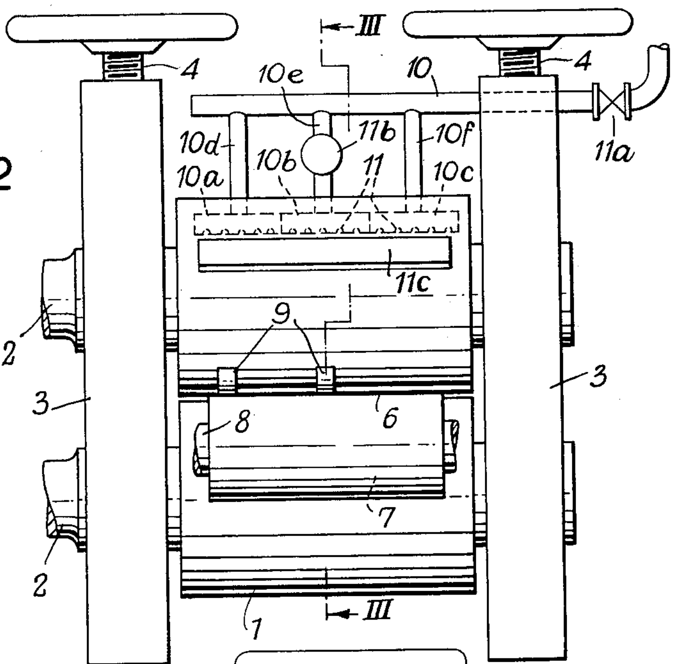
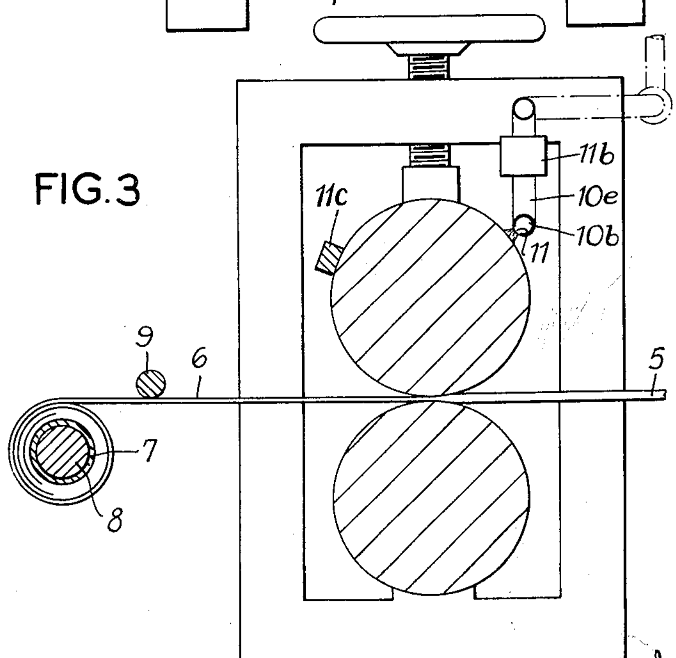


FIG.3



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MANUFACTURE OF METAL SHEET OR STRIP

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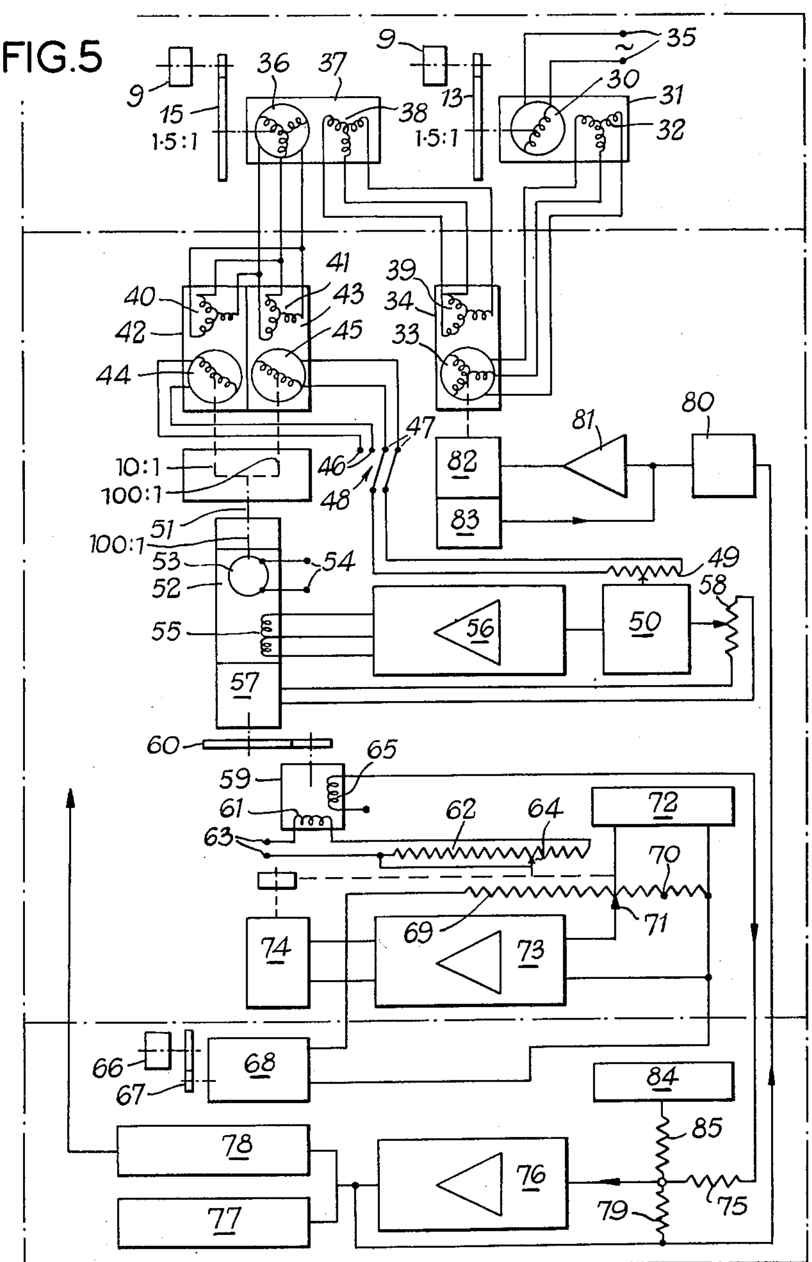
FIG.5



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MANUFACTURE OF METAL SHEET OR STRIP

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15 Claims. (Cl. 80—56)

This invention relates to improvements in the manufacture of metal sheet or strip and is particularly concerned with improvements in the method of and means for controlling the flatness or shape of the sheet or strip produced by passing the material through the bite of a pair of co-operating rolls in a rolling mill. The term "flatness" refers to the surface of the sheet or strip produced and the term "shape" refers to the cross-sectional shape of the sheet or strip. Sheet or strip may be considered to be of good shape when it does not possess a double curvature. Usually the cross-sectional shape is uniform throughout the length of the sheet or strip but the sheet or strip may taper along its length whilst still being of good shape.

In the manufacture of metal sheet or strip by passing the material through a pair of co-operating rolls in a rolling mill it is usual to provide at least one of the rolls with a cambered surface, initially by appropriately grinding the roll and additionally by superposing a thermal camber thereon, in order to compensate for deflections of the rolls due to the separating force exerted by the rolled material. Thus each cambered roll has a surface which is curvilinear in a plane containing the roll-axis, is circular in a plane transverse to the roll-axis, is symmetrical about a transverse plane passing through the centre of length of the roll-axis and has its greatest diameter in the last-mentioned plane when at its working temperature. During the rolling operation the thermal camber of the cambered roll surface is controlled by controlling the temperature gradient existing in the roll in a direction parallel to its axis. In the operation of the rolling mill the flatness or shape of the sheet or strip entering the bite of the co-operating rolls is retained or improved as required according to the shape of the surfaces of the rolls at the bite and this shape depends upon the initial shape of the surfaces of the co-operating rolls and the reactionary forces exerted on these surfaces at the bite by the material to deform these surfaces. These reactionary forces in turn depend upon the screw-down force applied to urge the rolls towards each other, the friction influenced by lubrication of the roll surface and the tension (if any) applied to the sheet or strip. The roll surface friction is usually substantially constant during the rolling operation and is difficult to vary during such operation. The remaining factors, namely the roll shape, the screw down force and the sheet or strip tension (if any) are capable of being varied during a rolling operation and are hereinafter referred to as the "controlling factors."

It is desirable that the surface of sheet or strip emerging from the co-operating rolls of a rolling mill should be flat and of good shape but it is frequently found that this is not the case and this defect is particularly undesirable in strip material which is too long to be corrected by subsequent flattening operations. Hitherto, it has been customary to assess the flatness or shape of the sheet or strip by visual inspection in the absence of a satisfactory instrument to measure it continuously during rolling, and the use of tension on the sheet or strip and high rolling speeds has made it increasingly difficult even for highly skilled operators to assess the flatness or shape and take the correct remedial action.

It is an object of the present invention to provide a method of continuously measuring the deviations from flatness and good shape of rolled sheet or strip as they occur in a rolling mill and to utilise the measurements to modify at least one of the controlling factors in the sense to correct for the deviation.

According to one feature of the present invention a method of controlling the flatness or shape of metal sheet or strip produced by passing the material through the bite of a pair of co-operating rolls in a rolling mill comprises applying at least two rollers or the like in non-slip frictional contact with the surface of the sheet or strip at spaced locations so as to be driven by the advancement of the sheet or strip from the bite, the modifying at least one of the controlling factors in the sense to maintain constant the angular velocity imparted to one roller relative to that imparted to the other roller.

Preferably the rollers are disposed with their axes of rotation in a common plane transverse to the direction of advance of the sheet or strip and one of the rollers is disposed substantially centrally of the width of the sheet or strip whilst the other roller is disposed between the one roller and one longitudinal edge of the sheet or strip.

According to another feature of the invention apparatus for carrying into effect the method according to either of the two immediately preceding paragraphs comprises at least two rollers adapted to contact the surface of the sheet or strip in a non-slip frictional manner at spaced locations so as to be frictionally driven thereby and means responsive to the difference between the angular velocities imparted to the rollers to provide a signal having a magnitude which is a function of such difference.

Preferably means is provided responsive to the difference signal automatically to modify at least one of the controlling factors in the sense referred to.

In order that the invention may be more clearly understood an example thereof will now be described with reference to the accompanying drawings in which:

FIGURE 1 is an elevational view of a roll for use in a rolling mill and having a camber which is exaggerated for the purpose of clarity;

FIGURE 2 is a somewhat diagrammatic elevational view of a strip rolling mill;

FIGURE 3 is a section taken on the line III—III of FIGURE 2;

FIGURE 4 is a block circuit diagram; and

FIGURE 5 is a circuit diagram showing in greater detail a circuit similar to FIGURE 4.

The roll 1 illustrated in FIG. 1 is shown with an exaggerated camber and it will be seen that it is substantially barrel-shaped, i.e. the roll 1 has a surface which is curvilinear in a plane containing the roll-axis, is circular in a plane transverse to the roll-axis, is symmetrical about a transverse plane passing through the centre of length of the roll-axis and has its greatest diameter in the last-mentioned plane when at its working temperature. In practice the camber is very slight and is usually formed by grinding the roll which may be ground initially to convex shape or it may be ground initially flat or concave to allow for thermal expansion during the rolling operation. Two such cambered rolls 1 are provided in the rolling mill shown in FIG. 2 and each is formed integrally with a shaft 2 carried in a frame 3. The shaft 2 of the lower roll 1 is carried in fixed bearings (not shown) and the shaft 2 of the upper roll 1 is movable towards the lower roll by means of screw-down members 4 whereby the force urging the two rolls 1 together is controlled.

This example is concerned with the manufacture of metal strip and the primary material indicated at 5 (FIG. 3) is fed to the bite of the rolls and emerges therefrom as the final strip 6. As will be appreciated the primary material 5 may have been pre-rolled to a predetermined thickness. The strip **6** is taken up on a positively driven roller **7** carried on a shaft **8** whereby tension is imparted to the strip **6**. Two measuring rollers **9** are arranged to bear on one surface of the strip **6** in non-slip frictional contact so as to be driven by the advancement of the strip **6**, the axes of these rollers **9** being contained in a common plane transverse to the direction of advancement of the strip **6**. The rollers **9** are preferably of equal diameters as shown, although they need not necessarily be so and one is disposed substantially centrally of the width of the strip **6** and the other is disposed between the centrally disposed roller **9** and one longitudinal edge of the strip **6**.

The angular velocity imparted to each roller **9** by the moving strip **6** is proportional to the length of the strip **6** passing that roller **9** in unit time. Thus, perfectly flat strip of good shape is uniform in length and will cause rollers **9** of equal radius to rotate with identical velocities whereas strip which is not flat or of good shape has a surface which is longer in some parts than others and will cause the rollers **9** to rotate at different angular velocities the difference in these angular velocities being proportional to the deviation from flatness of the strip. It will be seen therefore that the difference in the angular velocities imparted to the rollers **9** is a measure of the deviation from flatness and of good shape of the strip **6** and may be utilised to modify at least one of the controlling factors, i.e. the roll camber, the strip tension or the screw down force exerted on the rolls by the screw down member or members **4**.

In this example the camber of the upper roll **1** is controlled by means of an oil pipe **10** feeding pipes **10*a***, **10*b*** and **10*c*** extending parallel to the axis of the roll **1** by way of branch pipes **10*d***, **10*e*** and **10*f*** respectively. The pipes **10*a***, **10*b*** and **10*c*** are provided with a number of spraying apertures **11** along their length through which oil is sprayed on to the surface of the roll **1** on that part thereof advancing towards the bite of the rolls. The pipe **10*b*** is disposed between the pipes **10*a*** and **10*c*** so that the oil therefrom controls the temperature of the mid-part of the surface of the roll **1** parallel to its axis and the oil from the pipes **10*a*** and **10*c*** controls the temperature of the surface of the roll **1** along its marginal edges. A manually adjustable valve **11*a*** controls the oil flow to the pipe **10** and an automatically controlled valve **11*b*** controls the flow of oil to the pipe **10*b*** thereby controlling the flow of oil from the latter relative to the oil flow from the pipes **10*a*** and **10*c***. After the surface of the upper roll **1** has passed the bite, any oil remaining thereon together with dirt and metal slivers is wiped therefrom by a wiper **11*c***. Thus by suitably controlling the valve **11*b*** the oil flow from the spraying apertures **11** of the pipe **10*b*** may be controlled and hence the temperature gradient and the roll camber and strip shape may be controlled. This control may be exercised by an operator observing the difference in the angular velocities imparted to the rollers **9** or automatically in accordance with such difference.

The block schematic circuit diagram of FIG. 4 shows an apparatus for automatically utilising the difference in the angular velocities imparted to the rollers **9**.

One of the rollers **9** drives a synchro transmitter **12** through a gear **13** and the other roller **9** drives a synchro differential transmitter **14** through a gear **15**, the electrical output from the synchro differential transmitter **14** being a three-phase electrical signal with electrical rotation at the difference speed which is fed to a synchro control transformer **16**. The latter is a comparison element in a servo loop which causes the rotor of the transformer **16** to track the electrical rotation and the mechanism of the servo loop operates as a torque amplifier which produces an output of sufficient magnitude to be utilised to exercise the desired control. The servo loop comprises a demodulatotr **17**, a D.C. amplifier **18** and a servomotor **19** the output from which drives the high-speed end of a gear **20** the low-speed end of which drives the control transformer **16** to provide a mechanical monitoring feed-back. Stabilising feed-back is provided by a tachogenerator **21** mechanically coupled to the servomotor **19**. This tachogenerator **21** provides an output which is an integral function of the output from the differential transmitter **14** and hence provides a voltage analogue of the difference between the angular velocities imparted to the rollers **9**, and this output is amplified by amplifier **22** and utilised to provide a visual indication at **23** of the difference between the angular velocities for manual control purposes.

To correct for the influence of changing mill speeds, a second tachogenerator **24** is coupled to the mill-motor, mill rolls **1** or the strip **6** (indicated generally by the reference **25**) to provide a voltage analogue of the rolling speed. This voltage analogue is subtracted from a fixed reference voltage provided at **26** in an amplifier **27** so as to produce an output from the latter which is inversely proportional to the rolling speed and which is utilised to energise the field of the tachogenerator **21**. In this way the output of the tachogenerator **21** and the indication at **23** is a linear function of the quotient of the difference between the angular velocities imparted to the rollers **9** and the rolling speed and hence is a measure of the flatness of the strip or of the strip shape. An interlocking stabilising feed-back signal may be provided by feeding the amplified output of the tachogenerator **21** through a stabilising network **29** to the amplifier **18**.

The output from the tachogenerator **21** is compared in the amplifier **22** with a value corresponding to the desired shape of the strip **6** and the resultant output from the amplifier **22** is fed to a final controlling element **28** which controls at least one of the controlling factors, which in this example is the camber of the rolls **1** by controlling the valve **11*b*** and hence the oil supply through the spraying apertures **11** of the pipe **10*b***, in the sense to reduce the difference between the angular velocities imparted to the rollers **9**.

It will be appreciated that the output signal may be used to control the drive of a motor to the spindle **8** to control the strip tension or to control a screw-down motor connected to the members **4** to control the screw-down force.

It will be appreciated that the rollers **9** need not necessarily be of the same diameter in which case the difference between the angular velocities imparted to them will have to be compared with a reference value to obtain a signal useful for control purposes.

It will be further appreciated that if sufficiently accurate speed measuring elements are available they may be used in place of the synchros **12** and **14** to give a difference voltage which could be fed directly to the amplifier **22**, a computing element being provided to divide this signal by a voltage analogue of the mill speed and the units **16**, **17**, **18**, **19**, **20**, **21**, **26** and **27** being no longer required.

FIG. 5 illustrates an electric circuit similar to that of FIG 4 but in greater detail. In this example one roller **9** drives through gear **13** the rotatable winding **30** of a synchro transmitter **31** the fixed winding **32** of which is electrically connected to the rotatable winding **33** of a synchro differential transmitter **34**. The rotatable winding **30** is connected across terminals **35** to a source of A.C. supply. The other roller **9** drives through gear **15** the rotatable winding **36** of a synchro differential transmitter **37** the fixed winding **38** of which is electrically connected to the fixed winding **39** of the transmitter **34**. The fixed windings **40** and **41** of synchro control transformers **42** and **43** respectively are connected in parallel across the rotatable winding **36**. The respective rotatable windings **44** and **45** of the transformers **42** and **43** have their outputs respectively supplied across the fixed pairs of terminals **46** and **47** of a double-pole switch **48** the movable pair of contacts of which may be switched to take the output from either one of the rotatable windings 44 and 45 and apply it across a pre-set sensitivity resistor 49 to feed a phase-sensitive rectifier 50. The rotatable windings 44 and 45 are respectively geared through ratios of 10:1 and 100:1 to a shaft 51 geared through a ratio of 100:1 to a split-field motor 52 the armature 53 of which is connected across terminals 54 to a D.C. supply. The field winding 55 of the motor 52 is connected to the output of a D.C. amplifier 56 the input of which is connected to the output of the phase-sensitive rectifier 50. The motor 52 also drives a tachogenerator 57 having an output applied across a feed-back resistor 58 connected to the input side of the phase-sensitive rectifier 50. The motor 52 also drives a "square law" D.C. tachogenerator 59 through gearing 60, the tachogenerator 59 having a separately excited field and being capable of being used for multiplication. One winding 61 of the tachogenerator is connected in series with a linear wire-wound potentiometer resistor 62 of about 4K across terminals 63 connected to a D.C. supply of about 25 volts, the movable tapping 64 being connected to the one end of the resistor 62 connected directly to one of the terminals 63. The position of the tapping 64 therefore controls the magnitude of the field produced by the winding 61 and the output of the tachogenerator 59 produced in armature winding 65 is a function of the product of this field and the speed of rotation of the tachogenerator 59 driven by the gearing 60.

A roller 66 bearing upon the metal strip is driven at a speed which is a function of the speed of advance of the strip and drives through gearing 67 having a ratio of about 3:1 a permanent magnet tachogenerator 68 so as to produce an output of about 80 volts from the latter at a strip speed of 800 feet per minute. This output is applied across a 100K linear wire-wound potentiometer 69. The potentiometer 69 has a limit stop 70 at 10K from the high voltage end and the tapping 71 is connected to a source 72 of a reference voltage which is applied across the tapping 71 and the high voltage end of the potentiometer 69 and the input of an amplifier 73 the output of which is supplied to a motor 74 which drives both tappings 64 and 71 which are mechanically linked. The output of the winding 65 of the tachogenerator 59 is applied through a resistor 75 to the input of an amplifier 76 the output of which is fed both to an indicator 77 and an actuator 78 for the valve 11*b*. The output of the amplifier 76 is connected to the input of the latter through a feed-back resistor 79 and is also connected to a biased relay 80 connected through an amplifier 81 to a motor 82 connected to the rotatable winding 33 of the synchro differential transmitter 34. The motor 82 also drives a tachogenerator 83 the output of which is fed back to the input of the amplifier 81 to provide a stabilising loop. A reference voltage is supplied to the input of the amplifier 76 from a source 84 connected thereto through resistor 85.

The operation of this circuit will now be described. For the purpose of this description the fixed winding 32 of the synchro transmitter 31 may be considered to be connected directly across the fixed winding 38 of the synchro differential transmitter 37. It will be apparent that in this case the rotating fields produced in the fixed windings 40 and 41 of the transformers 42 and 43 is a function of difference in the velocity of rotation of the rollers 9 and the rotation of the windings 44 and 45 thereof will be a similar function. The movable contact of the switch 48 is connected across the terminals 46 or 47 to select the output either from the rotatable winding 44 or the winding 45 respectively driven by the motor 52 throuhg permanently meshed gearing of 1000:1 and 10000:1. The motor 52, phase-sensitive detector 50 and amplifier 56 provided with stabilising feedback from tachogenerator 57 track either transformer 42 or 43 according to the speed ratio selected and hence enable the apparatus to be made effective over a wide range of speed difference of the rollers 9. The motor 52 drives the tachogenerator 57 and hence the "square-law" tachogenerator 59 at a speed which is a linear function of the velocity difference of the rollers 9. The permanent magnet generator 68 provides an output which is an integrated function of the speed of advance of the strip measured by the roller 66 and this is inverted by the self-balancing potentiometer system 62, 69 and applied across the winding 61 of the "square-law" tachogenerator 59. The latter integrates the velocity difference signal from the rollers 9 and provides an output which is the product of this integral and the reciprocal of the integral of the velocity of the strip. This product is the desired signal and is compared in the amplifier 76 with the reference voltage from the source 84 to produce the desired indication in the indicator 77 and the appropriate operation of the valve 11*b* due to the actuator 78. In practice the reference voltage of the source 84 will usually be zero when the rollers 9 are of equal radii but it may be set up initially to a predetermined value where the rollers 9 are not of equal radii or adjusted from time to time to compensate for changes in the radii of the rollers 9 due to wear and can also be used to compensate for drift in the amplifier 56 although this could be better dealt with by providing a separate zero check. The source 84 may also be set up initially to a predetermined value when a given deviation from flatness is desired.

The synchro-differential transmitter 34 and the connections thereto, the motor 82, tachogenerator 83, amplifier 81 and relay 80 are provided to ensure a rapid electrical line-up of the rotating fields of the transmitters 31 and 37. Thus should transmitters 31 and 37 get out of phase when the apparatus is started up, the amplifier 76 will saturate and operate the relay 80 and cause the motor 82 to drive the rotatable winding 33 to bring the rotating fields into synchronism in a matter of seconds. When synchronism is nearly achieved the relay 80 opens and the motor 82 ceases to function.

When the apparatus is being used on strip material it is desirable to provide some protection for the rollers 9 if the strip should break.

The rollers 9 and transmitters 31 and 37 are advantageously housed in a substantially air-tight casing (not shown) which is only open to atmosphere where the peripheries of the rollers 9 project through slots in the casing to bear upon the surface of the strip. This casing is supplied with air under pressure which escapes through the slots and prevents oil and other deleterious matter entering the synchro transmitters. In order to ensure that the rollers 9 bear in non-slip contact with the strip it will be appreciated that the casing must be urged towards the strip with a predetermined force. Advantageously the rollers 9 bear against the underside of the strip and the casing is pneumatically urged towards the strip by means of a double-acting ram. A suitable switch is provided to be operated by the casing if the latter rises into the line of the strip advance as would happen if the strip breaks. The switch is then operated to reverse the ram and the casing is retracted. It is preferred to provide a shutter which is automatically operated to move over the casing between the rollers 9 and the strip when this occurs to protect the rollers.

It will be understood that where a number of pairs of rolls 1 are provided in series in a tandem rolling mill the signal derived from a pair of rollers 9 bearing on the strip 6 emerging from the bite of one pair of rolls 1 may be utilised to modify at least one of the controlling factors relating to a preceding or succeeding pair of rolls 1 in the series so as to ensure that the strip finally emerging from the mill shall have the desired flatness or shape.

It will be further understood that more than two rollers 9 may be provided across the width of the sheet or strip and switch means may be provided successively to compare the angular velocities imparted to pairs of such rollers.

When sheet is being rolled it is usually not placed under tension and in such a case the signal derived from the angular velocities imparted to the rollers 9 is utilised to modify the screw-down force applied to the rolls 1 and/or the camber of the roll or rolls 1.

It will be understood that the invention is applicable to controlling the shape of profiled sheet or strip material.

What I claim is:

1. In a rolling mill, in combination, a pair of cooperating rolls for passing through the bite thereof a metal strip; at least two rollers contacting the surface of the strip advancing from the bite of said rolls, said rollers contacting said surface of said strip at spaced locations thereon and being frictionally driven by advancement of said strip from said bite of said rolls; a synchro-transmitter driven by one of said rollers; a synchro-differential transmitter driven by the other of said rollers; means electrically connecting said transmitters to provide therefrom a three-phase electrical signal with electrical rotation which is a function of the difference in the angular velocities imparted to said rollers; and means controlled by said three-phase electrical signal for modifying the action of said pair of cooperating rolls for maintaining constant the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers.

2. In a rolling mill, in combination, a pair of cooperating rolls for passing through the bite thereof a metal strip; at least two rollers contacting the surface of the strip in non-slip frictional relation at spaced locations thereon so as to be frictionally driven by advancement of said strip; a synchro-transmitter driven by one of said rollers; a synchro-differential transmitter driven by the other of said rollers; said transmitters being electrically connected to provide a three-phase electrical difference signal having electrical rotation which is a function of the difference in the angular velocities imparted to said rollers; a further roller applied to the surface of said strip for rotation by advancement of the latter to measure the speed of advance of said strip from the bite of said rolls; means deriving from the rotation of said further roller a voltage which is an integral function with respect to the time of the angular velocity imparted to said further roller; means for balancing said voltage derived from said further roller against a reference voltage to derive a signal which is proportional to the reciprocal of said voltage; a square-law tachogenerator having a separately excited field derived from said signal proportional to said reciprocal of said voltage; said square-law tachogenerator being driven at a speed proportional to the electrical rotation of said three-phase difference signal to produce an output which is proportional to the product of the integral with respect to time of the angular velocity imparted to one roller relative to the angular velocity imparted to the other roller and the reciprocal with respect to time of the angular velocity imparted to said further roller.

3. A method of controlling flatness or shape of metal strip produced by passing the strip through the bite of a pair of cooperating rolls in a rolling mill including the steps of: applying at least two independent rollers in non-slip frictional contact with the surface of the strip at spaced locations, respectively, thereon so as to be independently driven by the advancement of the strip; and then modifying the roll shape of at least one of said rolls of said pair of cooperating rolls in accordance with the differences in the angular velocities, respectively, of said rollers to maintain constant the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers by the advancement of said strip at said spaced locations thereon.

4. In a rolling mill, in combination, a pair of cooperating rolls for passing through the bite thereof a metal strip; at least two independent rollers contacting the surface of the strip in non-slip frictional relation at spaced locations, respectively, thereon transversely of the direction of the advancement of the strip so as to both be simultaneously but independently driven by the advancement of the strip from the bite of said rolls; means responsive to the difference between the angular velocities imparted to said independent rollers, respectively, by the advancement of the strip to provide a difference signal which is a function of such difference in angular velocities; and means controlled by said difference signal for modifying the action of said pair of cooperating rolls for maintaining constant the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers by the advancement of the strip.

5. In the combination of claim 4, means responsive to the difference signal to automatically modify the roll shape of at least one of said pair of cooperating rolls to maintain the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers.

6. In the combination of claim 4, means responsive to the difference signal to automatically modify tension applied to the strip in the direction of its advancement through the bite of said rolls to maintain the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers.

7. In the combination of claim 4, means responsive to the difference signal to automatically modify screw-down force applied to said pair of cooperating rolls to maintain the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers.

8. In the combination of claim 4, means for flowing cooling oil to one of said rolls; valve means for controlling the flow of cooling oil to said one roll; and a second valve means for determining the quantity of the flow of cooling oil to said one roll; and said second valve means being responsive to said difference signal to control the volume of flow of cooling oil to said one roll.

9. In the combination of claim 4, a further roller applied to a surface of the strip for measuring the speed of advance of the strip from the bite of said rolls; means for deriving from the rotation of said further roller a voltage which is an integral function with respect to time of the angular velocity imparted to said further roller by said strip; and means for utilizing said voltage to integrate said difference signal and provide an output that is the product of such integral and the reciprocal of the integral of the velocity of said strip.

10. In the combination of claim 4, a further roller applied to a surface of the strip for rotation to measure the speed of advance of the strip from the bite of said rolls; means for deriving from the rotation of said further roller a voltage which is an integral function with respect to time of the angular velocity imparted to said further roller; and means for balancing said voltage against said difference signal to derive a signal which is proportional to the reciprocal of said voltage.

11. A method of controlling the flatness or shape of metal strip produced by passing the strip through the bite of cooperating rolls in a rolling mill, which method includes the steps of: applying at least two rollers in non-slip frictional contact with the surface of the strip at spaced locations thereon transversely of the direction of advancement of the strip so as to be driven by the advancement of the strip from the bite of said rolls; deriving an electrical signal from the rotation of said rollers having a magnitude which is a function of the difference of the annular velocities imparted to said rollers; and utilizing said electrical signal for modifying the action of said cooperating rolls to maintain constant the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers.

12. A method of controlling the flatness or shape of metal strip produced by passing the strip through the bite of cooperating rolls in a rolling mill, which method in-

cludes the steps of: applying at least two rollers in non-slip frictional contact with the surface of the strip at spaced locations thereon so as to be driven by the advancement of the strip from the bite of said rolls; deriving an electrical signal which is a function of the rolling speed and producing a control signal which is a function of the product of the difference of the angular velocities imparted to the rollers and the reciprocal of said rolling speed electrical signal; and utilizing said control signal for modifying the action of said cooperating rolls to maintain constant the angular velocity imparted to one of said rollers relative to the angular velocity imparted to the other of said rollers.

13. A method of controlling the flatness or shape of metal strip produced by passing the strip through the bite of cooperating cambered rolls in a rolling mill, which method includes the steps of: applying at least two rollers in non-slip frictional contact with the surface of the strip at spaced locations thereon transversely of the direction of advancement of the strip so as to be driven by the advancement of the strip from the bite of said cambered rolls; deriving an electrical signal from the rotation of said rollers having a magnitude which is a function of the difference of the angular velocities imparted to said rollers; and then utilizing said electrical signal to effect modification of the camber of at least one of said cambered rolls to maintain constant the angular velocity imparted to one roller relative to the angular velocity imparted to the other roller.

14. A method of controlling the flatness or shape of metal strip produced by passing the metal strip through the bite of cooperating rolls in a rolling mill in which said rolls have a force applied thereto urging said rolls toward each other, which method includes the steps of: applying at least two rollers in non-slip frictional contact with the surface of the metal strip at spaced locations thereon trnasversely of the direction of advancement of the strip so as to be driven by the advancement of the strip; deriving an electrical signal from the rotation of said rollers having a magnitude which is a function of the difference of the angular velocities imparted to said rollers; and then utilizing said electrical signal to effect modification of the force urging said cooperating rolls together to maintain constant the angular velocity imparted to one roller relative to the angular velocity imparted to the other roller.

15. A method of controlling the flatness or shape of metal strip produced by passing the metal strip through the bite of cooperating rolls in a rolling mill in which tension is applied to the metal strip, which method includes the steps of: applying at least two rollers in non-slip frictional contact with the surface of the strip at spaced locations thereon transversely of the direction of the advancement of the strip from the bite of said rolls; deriving an electrical signal from the rotation of said rollers having a magnitude which is a function of the difference of the angular velocities imparted to said rollers; and then utilizing said electrical signal to effect modification of the tension applied to the metal strip to maintain constant the angular velocity imparted to one roller relative to the angular velocity imparted to the other roller.

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