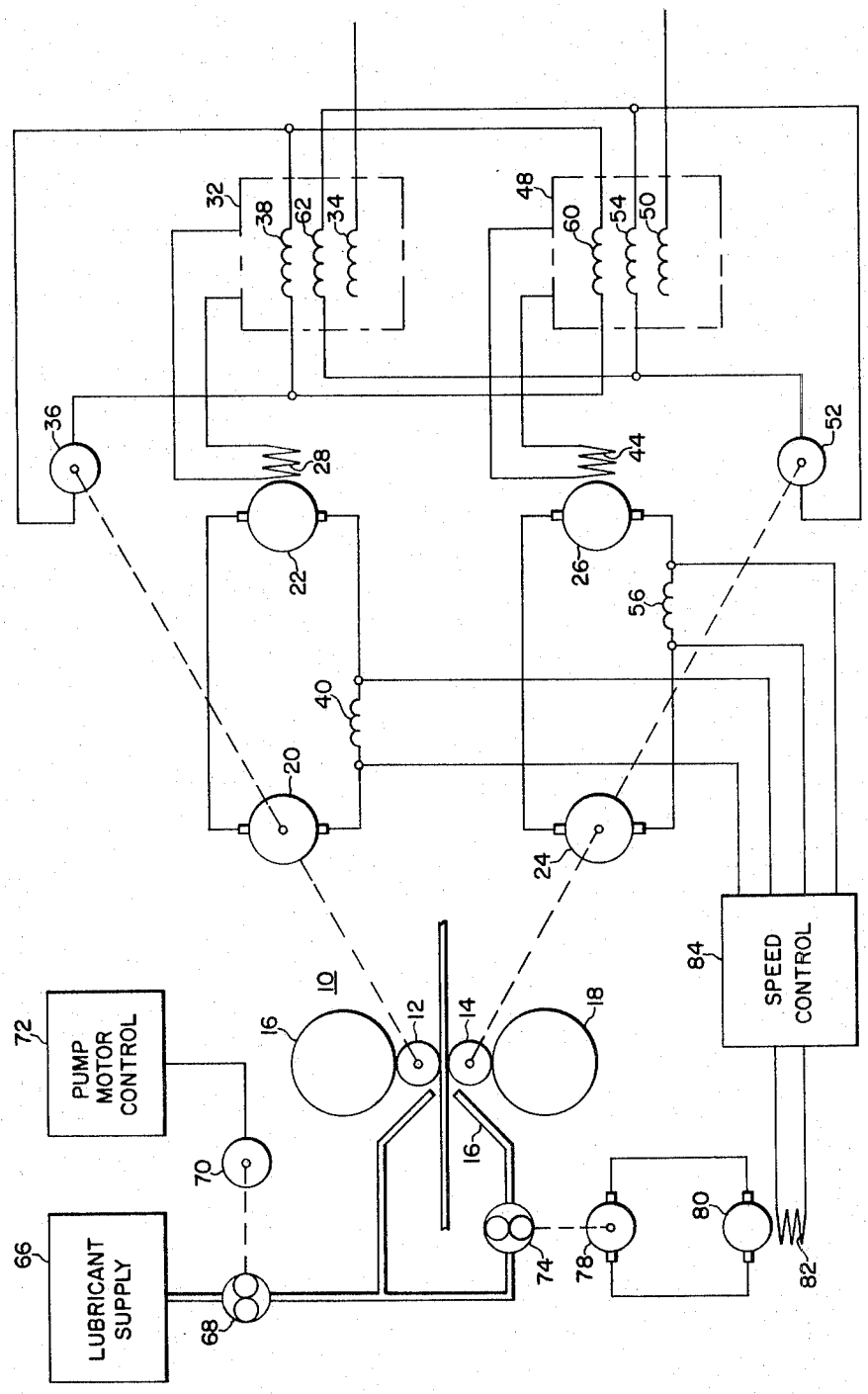
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ROLLING MILL CONTROL APPARATUS

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WITNESSES

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ROLLING MILL CONTROL APPARATUS

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The present invention relates in general to the cold rolling of metal sheet or strip workpieces in a rolling mill, and more particularly it relates to control apparatus for a cold rolling mill to effect a desired load or speed balance of the rolling mill relative to the motors driving respectively the cooperating top and bottom rolls of a cold reducing stand.

At the present time, high production cold reduction of steel strip workpieces is accomplished on cold rolling mills which consist of from three to six stands arranged in tandem. These mills can be driven by twin drive direct current motors, with no connection between the top roll and the bottom roll other than through the strip workpiece. It is the standard practice to supply to motors comprising one twin drive either from a common power supply bus arrangement for each stand, or in individual power supply loops for each half of the twin drive. Load balance for the direct current motors is accomplished by any of the conventional means of crossed series fields or separate load balance regulation working on either generator regulators or motor field regulators, or in some cases on both generator and motor regulators, The above practice has been reasonably successful, and there are many cold rolling mills in operation at the present time performing to some degree of satisfaction which are controlled in this manner. However, due to the difference in effective lubrication of the top of the strip compared to the bottom of the strip, the bottom roll drive motor usually requires more torque output than the top roll drive motor. Thusly, load balance requires that some torque be transmitted through the strip workpiece from one roll to the other to make up this torque difference. In some cases, it is not practicable to transfer this torque in this manner and the result is that the top roll actually runs faster than the bottom roll to result in scratching of the strip workpiece. On some cold rolling mills it has been necessary to reduce the amplification of the top motor control apparatus to control the scratching of the strip workpiece. On one recent mill application, the top and bottom rolls have been speed balanced and the motor load balance has been neglected entirely. This has resulted in good quality strip but the loading on the twin drive is unbalanced and results in very inefficient use of the available motor power.

It is an object of the present invention to provide improved control apparatus for a metal sheet or strip workpiece rolling mill, wherein a better operational loading balance is accomplished between the top roll motor and the bottom roll motor. In is an additional object of this invention to provide better and more effective speed and/or load balancing regarding the top roll motor and the bottom roll motor of a strip workpiece rolling mill.

It is a further object of the present invention to provide a better operation for a rolling mill by effecting improved lubrication between the strip workpiece and at least one of the top roll and the bottom roll in accordance with a predetermined desired operation of the rolling mill.

In accordance with the present invention a tandem cold rolling mill control apparatus is provided, including voltage regulators or speed regulators on the generators or power supply and flux regulators on the motor fields. It should be here understood that the present invention is equally applicable to a motor power supply including controlled rectifiers or the like apparatus. The operating

speed of the respective top roll motor and the bottom roll motor is balanced by working on generator voltage where separate loop power supplies are used. If a common power supply is used, the speed balance can be obtained by working on the motor fields. The desired load balance is obtained by operating on the lubrication pressure on the bottom of the strip by a small variable speed pump which will boost the basic strip lubrication pressure to the bottom of the strip as compared to the normal lubrication pressure supplied to the top of the strip to thereby maintain the desired main drive load balance.

The above objects and advantages in the operation of the control apparatus of the present invention will become more readily apparent from the following description and accompanying drawings in which there is shown control apparatus in accordance with the present invention as applied to a separate generator scheme for a twin drive. For simplicity the well known and conventional motor field regulators are not shown.

In the drawing there is shown a rolling mill stand **10** including a top work roll **12**, a lower work roll **14**, an upper backup roll **16** and a lower backup roll **18**. A top roll drive motor **20** is shown connected to the top roll **12** and is operative with a generator **22** in a conventional variable voltage control loop circuit. A drive motor **24** is connected to the lower roll **14** and operative with a control generator **26** in a conventional variable voltage control loop circuit. The top roll motor control generator **22** is provided with a field winding **28** energized by a regulator including a signal amplifier, such as the magnetic amplifier **32** having a plurality of control windings. A pattern winding **34** is energized with a predetermined reference operation for the generator **22**. A pilot generator **36** operative to sense the speed of the top roll drive motor **20** is connected to energize a control winding **38** of the magnetic amplifier **32** such that any above speed operation of the drive motor **20** results in an energization of the control winding **38** to reduce the speed thereof, and any below speed operation of the drive motor **20** results in the energization of the control winding **38** to increase the operational speed thereof.

The control generator **26** operative with the lower roll drive motor **24** is provided with a field winding **44**. A regulating signal amplifier is provided including a magnetic amplifier **48** having a desired pattern or reference operation control winding **50**. A speed sensing pilot generator **52** is coupled to the drive motor **24** for providing a control signal to energize a control winding **54** of the magnetic amplifier **48** such that any above speed operation of the drive motor **24** is thereby reduced and any below speed operation of the drive motor **24** is thereby increased.

The output signal from the pilot generator **36** operative with the top roll drive motor **20** is connected to a control winding **60** of the magnetic amplifier **48** for increasing the operating speed of the drive motor **24** when the top roll drive motor **20** is operating at a higher than is the lower roll drive motor **24**. The pilot generator **52** coupled to the drive motor **24** is connected to energize a control winding **62** of the magnetic amplifier **32** such that the top roll drive motor **20** is thereby caused to operate at substantially the same speed as is the bottom roll drive motor **24**.

There is provided for lubricating both the top surface and the bottom surface of the workpiece **64** operative with the rolling mill stand **10**, a lubricant supply **66** and a fluid pump **68** connected to be driven by a motor **70**, and a pump motor control **72** is operative to provide a predetermined supply of lubricant fluid to the top and lower surfaces of the strip workpiece **64**. In addition, there is provided a booster pump **74** operative with the

fluid channel 76 for supplying lubricant to the lower surface of the strip workpiece 64. A pump control motor 78 is connected to drive the booster pump 74 and is energized by a control generator 80 having a field winding 82 energized by a conventional speed control 84, which is responsive and connected to each of the armature current sensing devices 40 and 56 for the respective top roll drive motor 20 and lower roll drive motor 24.

Thusly, there is illustrated in the attached drawing control apparatus for providing the desired speed balance between the top roll drive motor 20 and the lower roll drive motor 24 of a given rolling mill stand 10, and for providing the desired load balance by operating on particularly the pressure of the supplied lubricant fluid for the lower surface of the strip workpiece 64 by means of a smaller capacity variable speed booster pump 74 operative to boost and vary the basic or reference strip lubrication pressure relative to the lower surface of the strip workpiece 64 and thereby to maintain the desired main drive operational balance.

In this respect the signal amplifier regulator operative with the top roll drive motor 20 energizes the control field 28 for the control generator 22 in accordance with the operating speed of the drive motor 20 as sensed by the coupled pilot generator 36. The signal amplifier regulator operative to regulate the operation of the lower roll drive motor 24 energizes the control field 44 of the control generator 26 in accordance with the operating speed of the drive motor 24 as sensed by the coupled pilot generator 52. The speed of the drive motor 20 is maintained in accordance with a desired relationship to the speed of the drive motor 24 through the provided cross coupling of the output signals from the respective pilot generators 36 and 52.

The load balance of the drive motors 20 and 24 is accomplished, by sensing the load on the top roll drive motor 20 through the current sensing device 40 and by sensing the load on the lower roll drive motor 24 through the current sensing device 56, through a pump motor speed control 84 operative with the control field 82 of the control generator 80 for varying the armature voltage of the pump motor 78 to thereby vary the operating speed of the pump motor 78 and the supply pressure through the conduit 76 of the lubricant fluid from the lubricant supply 66 as necessary to substantially balance and make the same the respective drive motor output torques and thereby the assumed load on the respective drive motors 20 and 24.

It should be noted, that other variations of the illustrated control apparatus are practicable and within the scope of the present invention. For example, a modification could be to effect the desired load balance by the signal amplifier regulators 32 and 48 being responsive to the armature currents of the respective drive motors 20 and 24, with provided cross coupling therebetween as desired. The motor speed signals from the respective pilot generators 36 and 52 could then be supplied to the pump motor speed control 84 to regulate the lubricant pressure supplied to the lower surface of the strip workpiece 64. Also, for rolling mill stands which operate from a single power supply, the illustrated speed balance could be operative on the motor field regulators.

While a preferred embodiment of the present invention has been disclosed, it is to be understood that the invention is capable of various adaptations and modifications within the spirit of the present invention.

I claim as my invention:

1. Control apparatus for a workpiece rolling mill having a pair of cooperating rolls, with said workpiece being positioned to pass between said pair of rolls, and including a first motor connected to drive a first of said rolls, a second motor connected to drive the second of said rolls, load balance control means operative with at least one of said rolls, first condition sensing means coupled

to said first motor for providing a first control signal in accordance with a predetermined operating condition of the first motor, second condition sensing means coupled to said second motor for providing a second control signal in accordance with a predetermined operating condition of the second motor, with said load balance control means being responsive to each of said first and second control signals for varying the relative load between said workpiece and at least one of said rolls in accordance with a predetermined relationship between said first and second control signals, and speed control means responsive to the speed of at least one of said motors for providing a predetermined speed relationship between said motors.

2. Control apparatus for a workpiece rolling mill having an upper roll and a lower roll, with said workpiece being positioned between and cooperating with each of said upper roll and said lower roll, and including a first motor and a second motor coupled to drive said rolls, load balance control means operative relative to said workpiece and at least one of said rolls, first load sensing means operative with said first motor for providing a first control signal in accordance with the loading of the first motor, second load sensing means operative with said second motor for providing a second control signal in accordance with the loading of the second motor, with said load balance control means being responsive to each of said first and second control signals for varying the load of the workpiece relative to at least said one roll in accordance with a desired relationship between the loading of the first motor and the loading of the second motor, and speed control means responsive to the speed of at least one of said motors for providing a predetermined speed relationship between said motors.

3. Control apparatus for a workpiece rolling mill having a pair of cooperating rolls, with said workpiece being positioned to pass between said pair of rolls, and including a first motor connected to drive a first of said rolls, a second motor connected to drive the second of said rolls, lubrication means operative to provide a lubricant between said workpiece and at least one of said rolls, first condition sensing means coupled to said first motor for providing a first control signal in accordance with a predetermined operating condition of the first motor, second condition sensing means coupled to said second motor for providing a second control signal in accordance with a predetermined operating condition of the second motor, load balancing control means operative with said lubrication means and responsive to each of said first and second control signals for varying the quantity of lubricant provided between the workpiece and at least said one roll in accordance with a predetermined relationship between said first and second control signals, and speed control means responsive to the speed of at least one of said motors for providing a predetermined speed relationship between said motors.

4. Balance control apparatus for a workpiece rolling mill having an upper roll and a lower roll, with said workpiece being positioned between and cooperating with each of said upper roll and said lower roll, and including a first motor coupled to drive the upper roll, a second motor coupled to drive the lower roll, speed control means responsive to the speed of at least one of said motors for providing a predetermined speed relationship between said motors, lubrication means operative to lubricate said workpiece relative to at least one of said rolls, first condition sensing means operative with said first motor for providing a first control signal in accordance with the operation of the first motor, second condition sensing means operative with said second motor for providing a second control signal in accordance with the operation of the second motor, and control means operative with said lubrication means and responsive to each of said first and second control signals for varying the lubrication of the workpiece in accordance with a desired relation-

ship between the operation of the first motor and the operation of the second motor.

5. Control apparatus for a workpiece rolling mill having upper and lower cooperating rolls, with said workpiece passing between said upper roll and said lower roll, and including a first motor coupled to drive the upper of said rolls, a second motor coupled to drive the lower of said rolls, workpiece treatment means operative to provide a predetermined treatment to said workpiece relative to the passage of the workpiece between said rolls, first motor operation sensing means coupled to said first motor for providing a first control signal in accordance with a predetermined operation of the first motor, second motor operation sensing means coupled to said second motor for providing a second control signal in accordance with a predetermined operation of the second motor, speed control means responsive to the speed of

at least one of said motors for providing a predetermined speed relationship between said motors, and workpiece treatment control means responsive to each of said first and second control signals for varying the treatment of said workpiece in accordance with a predetermined relationship between said first and second control signals.

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