DEVICE FOR STRIP MILL FOR DECIDING STRIP TENSION DISTRIBUTION ACROSS THE STRIP

Olivo Sivitoni, Kingston, Ontario, Canada, assignor to Almanna Svenska Elektriska Alltsieblaget, Vastern, Sweden

Filed Feb. 10, 1965, Ser. No. 431,563

3,324,695

Claims priority, application Sweden, Feb. 13, 1964, 1,725/64; Sept. 21, 1964, 11,291/64
18 Claims. (Cl. 72—15)

In order to measure the tension with which the coil rolls if the strip like material when it leaves the work rolls in a rolling mill, usually a device is used in which the strip is deflected with a known angle across a roll whose bearing rests on power measuring devices, so-called strip tension sensing devices. By keeping the wrapping angle constant, the output from the measuring device gives information on the strip tension. The device does not however give any information on the distribution of strip tension across the rolling direction, but only measures its total value. Because of the non-uniform goods or because the rollers are uneven or because of the uneven temperature distribution in the strip the reduction in a work roll can become uneven and thereby the extension and also the thickness of the strip becomes different over the strip. This means that the strip does not remain even when the strip tension ceases. Because the strip is subjected to the strip tension during the winding and rewinding on the roller, the unevenness becomes evident in the strip only when the strip tension ceases and thus it is not possible to control the causes of the unevenness. If it were possible to continually measure the distribution of the strip tension across the rolling direction during rolling, it would be possible in most cases to remove the causes of the unevenness, for example, by locally cooling the rollers or strip or by other measures.

With a device according to the present invention it is possible to continually control tension distribution across the strip in connection with the strip being fed across a roll. The invention is characterized in that the surface of the roll contains at least one pressure sensitive zone, which passes helically in relation to the longitudinal direction of the roll. The pressure sensitive zone is suited to be used with a device for tensioning members or transducers, containing at least one measurement part and a number of resilient elements, which elements are connected hysteresis-free with the measurement part and keep the transducers fixed in the pressure sensitive zone.

With the proposed device a permanent sensing of the distribution of the strip tension across the rolling direction is maintained. Through the helical location of the pressure sensitive zone on the roll the contact point of the strip with the pressure sensitive zone is moved across the strip and the movement is repeated for each rotation of the roll. This will be exemplified in connection with the description of the invention.

In the accompanying drawing FIG. 1 shows a strip roll for a rolling mill with the helically arranged pressure sensitive zone. FIG. 2 shows how a transducer can be arranged in a groove in the roll, while FIG. 3 shows another way of affecting a pressure sensitive zone. FIGS. 4 and 5 show a pair of different connections for taking out the signal from the pressure sensitive zone. In FIG. 6 a device for combining the signals supplied from the transducer for local tension with a signal supplied from a strip tension measuring device which corresponds to the strip average tension signal is shown. FIG. 7 shows an example of the appearance of the signal for local strip tension received from the transducer in the rolling mill and those parts of the signal which are taken out for special purposes in the device according to FIG. 6, and FIG. 8 shows in more detail the arrangements of the measuring means in the roll. FIG. 1 shows schematically a strip roll for a rolling mill with a pressure sensitive zone according to the invention. The pressure sensitive zone is arranged helically round the roller on the surface of the same and does not include a complete turn round the roller. The strip is bent at the strip roll to an angle of the size of about 10 degrees and thereby presses against the pressure sensitive zone over a short distance thereof. The distance depends on the diameter of the strip roll, the wrapping angle and the width of the pressure sensitive zone. When the strip rolls across the strip roll, the contact point between the strip and the pressure sensitive zone is periodically moved across the width of the strip along a line which forms an angle with the rolling direction of less than 90°. If the helical line has constant pitch, the contact point is moved along a straight line on the strip. The helical line does not compose a complete turn of the strip roll, since the strip for each rotation of the strip roll would then lie against the pressure sensitive zone at two places at the same time for a short moment.

The pressure sensitive zone is made suitably of a helical groove formed in the surface of the roll with constant pitch and with one or several transducers placed in the groove. If the groove contains only one transducer, this must be so long that the strip does not reach outside its ends. If several transducers are arranged in the groove, they are suitably spaced connected. The transducers are of a type which give an electrical output when they are subjected to mechanical force and the output is preferably proportional to the mechanical force. Since the strip lies against the pressure sensitive zone within a comparatively limited area, the total output becomes proportional to the pressure of the strip against the roller within that area, i.e. proportional to the strip tension in the part of the strip which lies against the strip roll within the same area. By this means a continuous cyclic sensing of the distribution of the strip tension across the rolling direction is produced.

FIG. 2 shows in section how according to the invention the pressure sensitive zone can be formed. On the outer surface of a strip roll a groove 2 is formed as a cavity in cylinder 1. The groove has a suitable horizontal bottom surface 3, while its side edges perpendicular to the bottom surface are constructed as a control edge 4. A transducer which is constructed of magnetostriuctive material consists of a measuring part 5 and four resilient elements 6 laterally directed from the measuring part, which are constructed in one piece with the measuring part or joined in some other hysteresis-free way to the measuring part. At its ends slotted furthest from the measuring part, the elements 6 are joined to each other two and two by means of the end pieces 7. These end pieces are provided with ledges 8, designed to cooperate with said control edges 4. The measuring part is provided at its lower side with a projection 9 which lies against the bottom of the groove. The measuring part has a similar projection 10 at its upper side. The length of the resilient elements 6 is so chosen that the transducer engages laterally against the vertical walls of the groove. Similarly the height of the end pieces 7 is chosen so that the resilient elements 6 keep the transducer fixed vertically by means of steps 3 engaging against the control edges 4 and the projection 9 against the bottom 3 of the groove. The transducer must be so fastened that the centrifugal force cannot overcome the force effected by the resilient elements 6 against the bottom of the groove.

In the measuring part 6 four holes 11, 12, 13 and 14 are formed. In the holes 11 and 12 an excitation coil 15 is arranged and it is connected to an excitation current source 16. The holes 13 and 14 are provided with a measuring...
winding 17 which is connected to a measuring instrument 18. The excitation coil generates in a known way a magnetic flux round the holes 11 and 12. The voltage induced in the measuring winding 17 becomes thereby dependent on the effects acting on the transducer.

In order to bridge the groove and to give the roller a smooth surface it is provided with a further relatively thin cylinder 19, which lies against the upper projection 10 of the measuring part. The part of the outer cylinder lying over the groove must be so pliable that it does not take up any considerable part of the pressure from the strip, but transfers it as much as possible to the transducer.

In FIG. 3 another way of effecting the pressure sensitive zone is shown. Rings 20 are punched out of magnetostrictive material, whose inner diameters correspond to the outer diameters of a billy roll forming a cavity cylinder 1. Near the outer ring edge two oblong holes 21 are punched, separated by a narrow part 22, which constitutes the measuring zone. The rings 20 are placed on the outside of the cylinder 1 so that good connection with this is provided and are displaced somewhat in relation to each other so that the holes 21 form two channels which pass helically round the edge of the roll in a way previously mentioned. An excitation coil 23 is placed in the channels which surround the narrow part 22, and with this forms an inductive element whose inductance depends on the force acting upon said narrow parts 22. Said narrow parts thus constitute the measuring zone of the transducer. In order that the transducer shall be as sensitive as possible, the measuring zone is made as narrow as possible. The tongues 24 situated above the holes constitute the elements which support the transducer, but which here also serve as return paths for the magnetic flux through the measuring zone. The outer surface of the cylinder is formed by the rings 20 which can be ground and can serve as working surface for the billy roll. By this means the strip will lie directly against the elements 24. In order to avoid wear on the elements it can however be suitable to have a cylindrical envelope 25 of strong material outside the cylinder formed by the rings 20.

When the strip during the rotation of the billy roll passes over the measuring zone 22 the inductance of the inductive element is changed and with the help of known measuring connection the pressure from the strip can be determined. It is also possible to arrange an equal inductance 26 which is not impressed by the tension of the strip, for example inside the billy roll and connect both the inductances known per se to a known measuring connection 27 with a measuring instrument 28 according to FIG. 4. By this means mistakes are avoided which depend on temperature changes, since both the inductances have substantially the same temperature.

At a variation of the invention, a further two holes 29 are punched in the ring 20 and these are situated diametrically opposite the two holes 21 described above. An excitation coil 30 is placed in the channels which are formed by the holes 29. If each of the excitation windings 23 and 30 are divided into two separate coils and the four partial coils are connected together in a bridge according to FIG. 5, the transition resistance is overcome, while brushes and slip rings only control the feeding and measuring branches. The disadvantage with this embodiment is however that the pressure sensitive zone comprises less than half the circumference of the billy roll, since there are two zones and they must not overlap each other and that by this the accuracy of measurement of the strain variations is only one half as great width the same wrapping angle of the strip.

In a further modification of the invention, the transducer shown in FIG. 2 is replaced by a sector of the ring which is shown in FIG. 3. This sector should then contain the two holes 21 and such large parts on both sides of the hole that sufficient mechanical rigidity of the segment is produced, as well as a sufficient magnetic return path for the flux through the measuring zone. Possibly the same constructive technique as shown in FIG. 2 can be used.

The transducer according to FIG. 2 is suitably built up of a number of elements which are punched out of magnetostrictive material, such as transformer steel plate. During assembly in the groove 2 the separate plate elements are each laid in the groove and are inserted with the lower projection 9 in a forward direction and then raised to a vertical position and pressed against the preceding element. The plate elements may be coated with a thermo-setting resin, which hardens after the individual elements are pressed together. Through this a very homogeneous measuring body is produced which is well secured in the groove.

In order to arrange the plate rings according to FIG. 3 in a simple manner so that the holes 21 and 29 form helical channels, each ring is provided with a positioning plug 31 extending in an inwards direction, which must be inserted in a corresponding helical groove on the outside of the cavity cylinder 1. FIG. 6 shows an arrangement for combining the signal produced from the transducer for local strip tension with a signal which corresponds to the strip average tension signal, which signal is produced by a strip tension measuring device, which is combined with the billy roll and controlled by this. Certain of the circuits in this arrangement are controlled by signals, which originate from an angle level indicator connected to the billy roll. The signal produced from the arrangement is fed to an instrument, for example a cathode ray oscillograph, which indicates how the strip tension varies along the width of the strip. The arrangement is based on the fact that there is a definite connection between the thickness and tension voltage in different longitudinal zones of the strip. This means that if the value of the strip tension in different longitudinal zones of the strip is determined, there will also be an indication of the thickness of the strip at different points across the strip. A zone here is defined as a ribbon of the strip whose breadth can correspond to the length along the roller shaft, which is exposed to an individual cooling mouth piece, so that the strip tension and thereby the length of each zone can be individually controlled by regulation of the cooling fluid in the corresponding mouth piece or group of mouth pieces.

In FIGS. 6 and 8, 1 shows the billy roll with a helically arranged transducer shown in FIG. 1. The billy roll is combined with a strip tension measuring device 32 known per se, which gives information on the total working strip tension on the strip. The billy roll is further provided with an angle level indicator 33, which controls an arrangement 36 which gives a signal which depends on the position of the billy roll and which signal is thus repeated periodically once per turn of the billy roll. The billy roll 1 is provided with signal transmission member 34, which can consist of slip rings and brushes, or which can be a threadless transmission or some other suitable arrangement. In an arrangement 35 a signal is produced which is proportional to the local strip tension acting on the transducer.

The strip tension measuring device 32 is combined with an arrangement 36 for manual adjustment of the actual width and thickness of the strip, so that a signal is produced over an arrangement 37 known per se, which corresponds to the value which the local strip tension would have if the strip were of equal thickness. This value is here called strip average tension signal. The strip tension measuring device is also provided with arrangements for compensating the drift of the transducer and the variation of the wrapping angle, which arises when the quantity of roll goods on the coil varies. Such arrangements are known, and therefore are not described in detail here.

If the correct value of the strip width and strip thickness is adjusted, and the strip tension is evenly distributed, i.e. the strip is of even thickness, the measured local strip
tension will agree with the average value of the local strip tension.
A gate circuit 39 is fed with the signal from the arrangement 38. The gate circuit has three outlets 91, 92 and 93. The outlet 91 is open during the interval A in FIG. 7, i.e. during the part of a turn of the billy roll when the strip does not lie against the transducer and when the output signal from this is zero. The outlet 92 is open during interval B, which comprises a relatively large part of the part of one turn of the billy roll when the strip lies against the transducer. The outlet 93 is open during interval C which comprises a relatively small part of interval B, comprises suitably the part of one turn when the central part of the strip lies against the transducer. From the three outlets, control signals for controlling arrangements are taken out, which will be described later.

The output signal from the arrangement 35 is fed to a summarizing arrangement 40, whose outlet 41 is connected with a zero adjusting arrangement 42. This can consist of a D.C. fed potentiometer or some known electronic arrangement. The zero adjusting arrangement is connected to the summarizing arrangement 40 and is controlled from the outlet 91 of the gate circuit 39. When the outlet 91 is open, the zero adjusting arrangement 42 stabilizes the output signal from the summarizing arrangement 40 is zero. This adjustment is made during the interval A in FIG. 7, when the signal from the arrangement 35 is zero and thereby any possible drift of the transducer in the billy roll is compensated for.

The summarizing arrangement 40 is connected to a sensitive adjustment arrangement 43, which is controlled from the outlet 91 of the gate 39 and which therefore is workable only during interval A. The signal from the summarizing arrangement 40 passes the sensitive adjustment arrangement 43, which is controlled from the outlet 91 of the gate 39 and which therefore is workable only during interval A. The signal from the summarizing arrangement 40 passes the sensitive adjustment arrangement 43, which is fed partly to a second summarizing arrangement 44, and partly to a third summarizing arrangement 45. To the third summarizing arrangement 45 the signal generated in the arrangement 37 is also fed, which corresponds to the average strip tension value and the difference between the two signals is fed to an integrator 46. The integrator is rendered operative by an impulse from the outlet 92 of the interval B, and thus integrates the difference between the two signals during said interval and feeds the result to the sensitive adjustment arrangement 43, where the fed integral is stored. During interval A when the outlet 91 of the gate 39 is first opened, an adjustment of the sensitivity in the arrangement 43 is made. During the interval the measuring signal is zero and an adjustment of the arrangement 43 can therefore be made without disturbing the measuring value. Adjustment of the sensitivity should be done therefore in such a way that normally at each moment only a small part of the measuring area of the transducer is used, since otherwise drift of the transducer might cause abnormally large or small signals which would make the picture on the oscillograph screen inconveniently large or small. Through the existing sensitive adjustment a correction of the sensitivity for each turn of the billy roll is made, which contributes to a stable signal to the oscillograph.

In the summarizing arrangement 44 the difference between the signals for local strip tension and the average strip tension is formed, which comes from the arrangement 37. The signal difference passes a filter 47 and is fed thereafter to a fourth summarizing arrangement 49, which is arranged for affecting an automatic centering of the picture 49. This arrangement works during a short interval C, which is suitably located at the part of a rotation of the billy roll, when the middle of the strip lies against the transducer in the billy roll and causes the centre point of the picture on the oscillograph screen placed along the X-axis to lie always on this axis. The advantage with this is that there is always the largest possible space for the pattern in the direction of the Y-axis. After centering the picture in the arrangement 48, the signal is fed to the vertical axis of the oscillograph 50. The horizontal axis of the oscillograph is fed with a signal from the arrangement 38, which signal is proportional to the axial position of that part of the transducer in the billy roll which is in contact with the strip.

On the screen a picture is thus produced which shows how the strip tension varies across the rolling direction and with the middle of the picture situated in the centre of the screen. The signal corresponding to the picture can of course as known per se be used for controlling arrangements in the rolling mill, for example the previously mentioned cooling mouth pieces, so that the strip becomes thicker in those parts that are too thin and the strip tension is evenly distributed over the strip.

1. In a strip mill having a billy roll, means for control of the distribution of tension across the strip as the rolled goods are fed across the billy roll, comprising at least one pressure sensitive zone on the surface of the billy roll which extends helically in relation to the longitudinal direction of the billy roll, and means connecting said tension distribution control means to said pressure sensitive zone.

2. In a mill according to claim 1, said pressure sensitive zone comprising transducer means with at least one measuring part and a plurality of resilient elements connected in a hysteresis-free manner with the measuring part, and means holding the transducer means fixedly in the pressure sensitive zone.

3. In a mill according to claim 1, said billy roll comprising a cylinder formed of rings of magnetostriuctive material, each of said rings having two adjacent holes therein, the holes of the rings together forming two helical channels, the part of each ring between the holes constituting an intermediate pressure sensitive part.

4. In a mill according to claim 3, said holes in the rings being elongated with substantially arcuate longitudinal center lines curved about the cylinder axis.

5. In a mill according to claim 4, said holes being two in number and being situated at the same radial distance from the cylinder axis.

6. In a mill according to claim 5, an excitation coil arranged in the channels and forming a measuring inductance, a comparison inductance arranged inside the cylinder, and a measuring bridge connecting said inductances.

7. In a mill according to claim 6, said holes being four in number and being arranged in two pairs situated diametrically opposite with respect to each other.

8. In a mill according to claim 7, an excitation coil arranged in the two channels in each group of holes, each coil being divided into two similar parts, and a measuring bridge connected to said four parts.

9. In a mill according to claim 3, a cylindrical casing of strong material surrounding said cylinder.

10. In a mill according to claim 3, an excitation coil arranged in the channels and surrounding said intermediate parts.

11. In a mill according to claim 1, in which said pressure sensitive zone is composed of at least one helical groove in the billy roll and transducers arranged in the groove, each of said transducers comprising a measuring part and a plurality of resilient elements extending from said measuring part, and means in said roll for holding said resilient elements.

12. In a mill according to claim 11, in which said groove includes surfaces inwardly directed towards the roll axis, said resilient elements comprising, for each transducer, four elements, and means carried by the ends of said elements situated furthest from the measuring part for engaging against said inwardly directed groove surfaces.

13. In a mill according to claim 11, said groove being provided with outwardly extending edge portions spaced
from the surface of the billy roll, the outer surfaces of said edge portions constituting said inwardly directed groove surfaces.

14. In a mill according to claim 11, a thin metal cylinder surrounding said billy roll covering the groove and lying against the transducer.

15. In a mill according to claim 1, said pressure sensitive zone containing a plurality of transducers, the output signal of each transducer being proportional to the pressure at which the strip lies against such transducer and which is thus proportional to the local working tension on the billy roll, said billy roll being provided with tension measuring means, and means connected to said tension measuring means to correct the output signal thereof to make it proportional to the average strip tension, and a summarising arrangement connected to said transducers and to said tension measuring means to give the difference between said two output signals.

16. In a mill according to claim 15, means for automatic zero adjusting of the signal for local strip tension during the time when the strip does not lie against the pressure sensitive zone of the billy roll.

17. In a mill according to claim 15, having means connected to said summarising arrangement for integrating the difference between said two signals during an arbitrary part of the time during which the strip lies against the pressure sensitive zone.

18. In a mill according to claim 17, a sensitive adjusting arrangement fed partly by said integrated difference signal and partly by the signal for local strip tension, and connected to the output of said adjusting arrangement to compensate for drift at the transducer.

No references cited.

WILLIAM W. DYER, Jr., Primary Examiner.

G. A. DOST, Assistant Examiner.