Feb. 6, 1962 L. HORNBOSTEL 3,019,511

CROWNED ROLL

Filed Feb. 15, 1961

Fig. 1

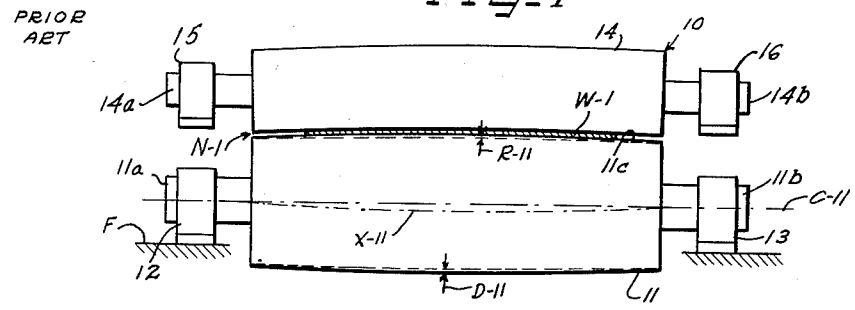


Fig. 2

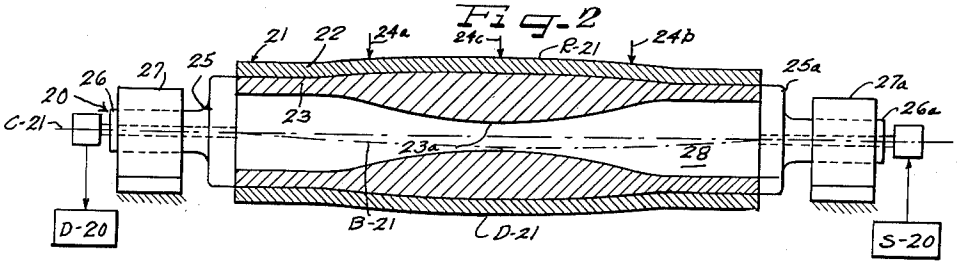


Fig. 3

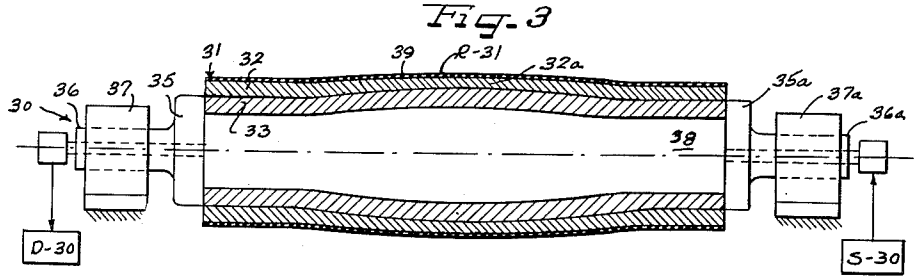
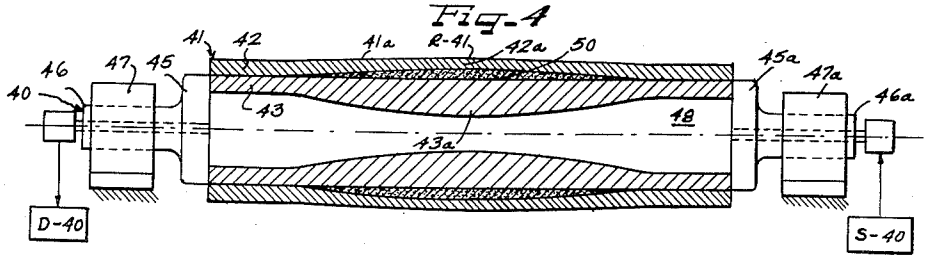


Fig. 4



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3,019,511
CROWNED ROLL

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This invention relates to a structure for a roll whose axis is subject to deflection in response to load applied to the roll, and more particularly, to a structure for such a roll wherein there may be obtained a predetermined and variable "crown" or variation in the outer peripheral dimension of the roll.

Although the instant invention may be useful in a number of arts, it is particularly useful in the paper machine art and will be described primarily in connection therewith. In paper machines, there are a number of different types of rolls of substantial size which are subjected to loads tending to deflect such rolls centrally. For example, wire return rolls in a Fourdrinier paper machine are subject to a load tending to effect central deflection thereof by virtue of the weight of the rolls themselves and of the Fourdrinier wire carried by the rolls, the tension on the Fourdrinier wire, and, in the case of a driven roll, the force component resulting from the resistance or reaction of the wire itself to the driving force. These forces tend to deflect the roll downwardly in the middle and this results in an undesirable guidance of the traveling wire, which it has been found advantageous to avoid by counteracting the tendency for downward deflection of the return roll in one manner or another.

In addition, in press couples, calender stacks, etc. the web passes through a nip between a pair of superimposed rolls whereat the web is subjected to pressures. The pressures thus applied at such nip tend to load the rolls and deflect the same. Such deflection results in an undesirable application of forces across the nip and other undesirable operating features; and such deflection is often corrected in paper machines by "crowning" of one or both rolls. The crowning of the roll requires accurate and expensive finishing of the roll surface so as to obtain a slightly greater roll diameter in the central portion of the roll; but such crowning is carried out on the basis of a predetermined set of force conditions and may not be satisfactory for operation under a different set of force conditions. Accordingly, crowning of rolls often does not afford satisfactory operation for many different types of operating conditions.

In other arts relating to paper machines, such as the coating of paper or fabrics with plastic materials, pressure or calender rolls are also used. Also, paint mixing roll systems or the like are subject to the buildup of forces in the central portion of pressure nips which tend to cause central deflection of the rolls and result in non-uniform and/or other undesirable conditions across the width of such press nips. In each of the roll systems of the prior art just mentioned, it is ordinarily possible to provide a roll having a given crown which affords satisfactory operation for a given set of operating conditions (primarily a given set of load conditions for the roll). The difficulty, however, is that changes in these operating conditions may and often do result in an unsatisfactory operation for such a roll which has been crowned in a predetermined manner for operation under a different set of conditions.

The instant invention affords a simple but unique roll structure wherein limited but very significant variation in the crowning of the roll is permitted, without the necessity of machining or otherwise refinishing the roll surface. The instant invention provides a very sturdy and reliable roll structure wherein the crown may be varied by the simple expedient of varying the temperature of the roll

itself, or a functional part of the roll. The instant invention is thus particularly well adapted for uses wherein temperature control of the operating surface of the roll is not particularly critical (so that temperature control of the roll itself may be accurately maintained without outside interference), but another aspect of the instant invention provides for a roll structure which comprises heat insulative means interposed between the functional, temperature-sensitive component of the roll and the operating surface thereof.

In the instant invention, there is provided a roll construction formed of an outer shell and an inner shell rigid therewith. Both of the shells are preferably formed of structural metal, and one of the shells has a substantially lower coefficient of thermal expansion than the other. Means are also provided for heating one of the shells. The ratio of cross-sectional area (i.e. annular area) of the inner shell to that of the outer shell is varied to a substantial extent across the width of the shells, or the width of the roll. In this arrangement, heating of the shell having the higher coefficient of thermal expansion effects the maintenance of a greater outer peripheral dimension (or "crown") in the region of the roll wherein there is a greater ratio of cross-sectional area of the shell that is formed of material having the higher coefficient of thermal expansion as compared to the cross-sectional area of the shell formed of material having the lower coefficient of thermal expansion.

The exact contour which the outer periphery of the roll will have thus depends not only upon the relative cross-sectional areas of the inner and outer shells (which is a structural aspect of the roll that requires rebuilding to change) but also upon the temperature at which the shell elements (and particularly the shell element having the higher coefficient of thermal expansion) are maintained. It will be appreciated that variation in this temperature can be readily accomplished without the disadvantages of rebuilding the roll or remachining the surface.

It is, therefore, an important object of the instant invention to provide an improved roll structure for rolls subject to deflection in response to loads applied thereto. It is another object of the instant invention to provide an improved roll assembly wherein the simple expedient of temperature control may be used to effect crowning of the roll in a predetermined manner.

Yet another object of the instant invention is to provide a roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, and means for heating the inner shell, the ratio of cross-sectional area of the inner shell to the outer shell being greater at the center of the roll than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

Other and further objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed disclosure thereof and the drawings attached hereto and made a part hereof.

On the drawings:

FIGURE 1 is a diagrammatic illustration showing the two lower rolls of the stack of rolls, illustrating in exaggerated form the manner in which such rolls may be deflected during a specific correlation among the essential control factors in a calender stack of the prior art;

FIGURE 2 is an essentially diagrammatic cross-sectional view of a roll assembly embodying the invention;

FIGURE 3 is a view corresponding to that of FIGURE 2 but showing another embodiment of the invention; and

FIGURE 4 is a view corresponding to FIGURES 2 and 3, but showing still another embodiment of the instant invention.

As shown on the drawings:

In FIGURE 1, a bottom portion of a calender stack, indicated generally by the reference numeral 10, is shown comprising a king roll 11 at the bottom mounted on suitable bearings 12 and 13 which are in turn firmly secured to a fixed mounting such as a floor F. Immediately above the king roll 11 is a calender roll 14 which, in turn, is mounted for rotation in bearings 15 and 16. Actually, the roll 11 is provided with a left hand stub shaft 11*a* or shaft element which is rotatably received by the left hand bearing 12 and a right hand stub shaft 11*b* which is rotatably received by the right hand bearing 13. The roll 14 is also provided with a left hand stub shaft 14*a* rotatably received by the left hand bearing 15 and a right hand stub shaft 14*b* rotatably received by the right hand bearing 16.

As will be noted, the axis X–11 for the roll 11 is deflected downwardly below a horizontal or center line C–11 at the middle of the roll 11 and this is caused by the load applied to the roll 11 by the weight of the roll 14 (and any other rolls thereabove). This weight is transmitted through the sheet of paper (shown in exaggerated thickness at W–1) passing through the nip between the rolls 11 and 14. In the calender 10, however, the central portion of the top surface of the roll 11 is still crowned so as to extend a distance R–11 above the outer extremities of the roll 11, and the bottom surface of the roll 11 is downwardly bowed still a greater distance D–11. The amount of operating crown R–11 depends upon the amount of original crown formed on the roll 11 and the total weight of the calender stack of rolls 14, etc. mounted thereabove. As will be appreciated, if it is desired to operate a calender with substantially no operating crown (R–11) in the king roll 11, the initial crown of the king roll 11 and the total weight of the calender rolls 14, etc. are correlated so as to obtain substantially no operating crown. If, however, it then becomes desirable to make a change in the operation of the prior art calender by using less calender rolls in the stack, then a greater operating crown R–11 will be obtained. This may possibly result in an undesirable pressure distribution at the portion of the web W–1 passing through the nip N–1. The same is true with respect to variations in load which may be applied to any other crowned roll in a paper machine or other device.

In many of such prior art devices, the crown initially formed on the roll being subjected to the load is just sufficient to permit the roll to deflect in response to this predetermined load to such an extent that the roll presents a substantially flat (usually horizontal) nip defining surface. It will be appreciated that any variation from such predetermined load will, however, necessarily result in a deviation from the desired flat or level contour of the operating surface or nip defining line of the roll (herein designated 11*c*).

Referring now to FIGURE 2, it will be seen that the assembly of the instant invention indicated generally by the reference numeral 20 comprises a roll 21 whose centroidal axis (C–21) in the unloaded condition of the roll 21 here shown is subject to deflection, when the roll is loaded. (It will be appreciated that the deflections and crowns indicated in FIGURES 1 and 2 are greatly exaggerated for purposes of simplifying the disclosure.) As indicated diagrammatically in FIGURE 2, the axis C–21 is a center line for the roll 21 which would be substantially straight or horizontal in the view of FIGURE 2, if the roll 21 were not subjected to any loading forces including the load of its own weight. The roll 21 is, however, subjected to a load across its entire width, including the load of its weight and the load of an upper roll which is represented diagrammatically by arrows 24*a*, 24*b* and 24*c*, although such load is desirably applied uniformly across the width of the roll 21. This load, as in the case of the load applied to the king roll 11 of FIGURE 1, results in a central deflection of the axis of the roll 21 indicated in dashed lines at B–21, plus a nominal or "zero" upper crown in the region of R–21 and a larger lower crown in the region D–21. In accordance with the knowledge of the prior art the roll 21 may be constructed so as to have a predetermined operating crown R–21 where it is subjected to predetermined load conditions (24*a*, *b*, *c*); but in contrast to the prior art, the operating crown R–21 in the roll of the invention can be varied within predetermined limits and in a predetermined manner, by means of a simple expedient of temperature control.

As shown in FIGURE 2, the roll 21 consists of an outer shell 22 and an inner shell 23 rigid therewith. The shells 22 and 23 are preferably formed of structural metal and are rigidly secured together by conventional means.

The mounting of the roll 21 is conventional in most respects; and it involves suitable allochiral head elements 25, 25*a* mounting the roll 21 for rotation via stub shafts 26, 26*a* integral with their respective heads 25, 25*a* and carried in suitable bearings 27, 27*a*. The stub shafts 26, 26*a* are hollow entering into the hollow interior 28 of the roll 21. Conventional means indicated diagrammatically are provided for heat exchange fluid in the hollow interior 28 of the roll 21 whereby the inner shell 23 (and the outer shell 22) may be subject to temperature changes.

As indicated in FIGURE 2, hot oil from a source S may be introduced via the stub shaft 26*a* and head 25 into the interior 28 for effecting heating of the roll 21; and spent oil may be withdrawn via the head 25 and stub shaft 26 into a drain D, from which the oil may be heated and recirculated to the source S. If less than room or normal operating temperature is desired, cooling heat exchange liquid may be used instead. Also, the hollow interior 28 of the roll 21 may be filled with liquid sodium and equipped with a steam coil for temperature control thereof.

Referring to the specific details of the shell assembly, it will be seen that the outer shell 22 is of substantially uniform annular thickness. In contrast, the inner shell 23 is of non-uniform annular thickness, having a substantially greater annular thickness in the central portion 23*a* thereof. Expressed in other terms, the (annular) cross-sectional area of the outer shell 22 is substantially uniform; whereas the (annular) cross-sectional area of the inner shell 23 is varied substantially; and, as a consequence, the ratio of the cross-sectional areas of the inner shell 23 and outer shell 22 are varied across the width of the roll 21 to a substantial extent, with such ratio being greater at the center of the roll 21 than at the ends thereof. The inner shell 23 is formed of a material such as bronze having a relatively higher coefficient of thermal expansion, as compared to the outer shell 22 which is formed of a material such as stainless steel. In the case of materials used in either of the shells 22, 23, it will be appreciated that Poisson's ratio is approximately the same (or at least in the same range for structural metals); and the modulus of elasticity or Young's modulus for the materials is approximately the same (or at least within the same range for structural metals, i.e. about 10 to 30×10^6 lbs./in.^{2}). Preferably the ratio of Young's moduli for the inner and outer shells is in the range of 2:1 to about 1:2.

With respect to the coefficient of thermal expansion for the materials used in the inner and outer shells 22, 23, it will be appreciated that these materials should also have approximately the coefficients of thermal expansion of structural metals, which is within the range of about 2 to about 15×10^{-6} in./in./° F. One of the shells (pref-

erably the inner shell 23) has a substantially greater coefficient of thermal expansion, however than that of the other shell. The difference in coefficient of thermal expansion between the two materials should be in the range of about 1 to 10×10^{-6} in./in./° F. For example, in a preferred embodiment the inner shell 23 is formed of bronze having a coefficient of 10 to 11×10^{-6} in./in./° F. and the outer shell 22 is formed of stainless steel having a coefficient of about 5 to 7×10^{-6} in./in./° F. Other materials having a relatively high coefficient of thermal expansion such as brass or aluminum may be used in place of the bronze; and other materials having a relatively low coefficient of thermal expansion such as iron alloys, Inconel, etc. may be used in place of the stainless steel.

The roll 21 is, of course, designed so that during the various temperature changes the operating crown may be varied and the materials used will be subjected only to relatively safe stresses. The manner in which variations in the crown may be obtained in response to variations in temperature by virtue of the use of materials having different coefficients of thermal expansion and the use of a shell structure wherein there are variations in the ratios of cross-sectional areas or annular thicknesses between the two shells can be demonstrated by calculation. In calculating the crown on a roll embodying the invention having the structure shown in FIGURE 2, the following definitions are employed:

R_{m1}=mean radius of outer shell 21
R_{m2}=mean radius of inner shell 22
R_{o1}=outer radius of outer shell 21
R_{o2}=outer radius of inner shell 22
R_{i1}=inner radius of outer shell 21
R_{i2}=inner radius of inner shell 22
t_1=annular thickness of outer shell 21
t_2=annular thickness of inner shell 22
E_1=Modulus of Elasticity (Young's Mod.) of shell 21
E_2=Modulus of Elasticity (Young's Mod.) of shell 22
α_1=coefficient of thermal expansion of shell 21 (in./in./° F.)
α_2=coefficient of thermal expansion of shell 22 (in./in./° F.)
V_1=Poisson's ratio for shell 21
V_2=Poisson's ratio for shell 22
S_1=circumferential stress for shell 21
S_2=circumferential stress for shell 22
p=pressure (p.s.i.) between the shells 21, 22
Δ_{D1}=change in diameter of shell 21
Δ_{D2}=change in diameter of shell 22
Δ_T=change in temperature (° F.)

Due to given p:

$$\Delta_{D1}=+\frac{2pR_{m1}^2}{E_1t_1}\left(1-\frac{V_1}{2}\right)$$

$$\Delta_{D2}=-\frac{2pR_{m2}^2}{E_2t_2}\left(1-\frac{V_2}{2}\right)$$

Due to ΔT:

$$\Delta_{D1}=+2R_{m1}(\alpha_1)(\Delta T)$$

$$\Delta_{D2}=+2R_{m2}(\alpha_2)(\Delta T)$$

Total Δ_{D1}=total Δ_{D2}:

$$\frac{2pR_{m1}^2}{E_1t_1}\left(1-\frac{V_1}{2}\right)+2R_{m1}(\alpha_1)(\Delta T)=\frac{-2pR_{m2}^2}{E_2t_2}\left(1-\frac{V_2}{2}\right)+2R_{m2}(\alpha_2)(\Delta T)$$

$$R_{m1}(\alpha_1)(\Delta T)-R_{m2}(\alpha_2)(\Delta T)=-p\left[\frac{R_{m1}^2}{E_1t_1}\left(1-\frac{V_1}{2}\right)+\frac{R_{m2}^2}{E_2t_2}\left(1-\frac{V_2}{2}\right)\right]$$

$$\Delta T[R_{m2}\alpha_2-R_{m1}\alpha_1]=p\left[\frac{R_{m1}^2}{E_1t_1}\left(1-\frac{V_1}{2}\right)+\frac{R_{m2}^2}{E_2t_2}\left(1-\frac{V_2}{2}\right)\right]$$

Assuming $t_2\geqq t_1$; then use

$$p=\frac{S_1t_1}{R_{m1}}$$

$$\Delta T[R_{m2}\alpha_2-R_{m1}\alpha_1]=S_1\left[\frac{R_{m1}}{E_1}\left(1-\frac{V_1}{2}\right)+R_{m2}\left(1-\frac{V_2}{2}\right)\frac{R_{m2}t_1}{R_{m1}t_2}\right]$$

Example

Assume shell 21 is a 440 stainless steel shell with 40 inch outside diameter; R_{m1}=19.5 inches; t_1=1.00 inch; $E_1=28.5\times10^6$ lbs./in.^{2}; $\alpha_1=5.6\times10^{-6}$ in./in./° F.; and V_1=0.26.

Assume shell 22 is a bronze shell with $E_2=14\times10^6$ lbs./in.^{2}; $\alpha_2=10.4\times10^{-6}$ in./in./° F.; V_2=0.33; t_2 at center=5.00 inch (therefore, R_{m2}=16.5); t_2 at ends=1.00 inch (therefore, R_{m2}=18.5).

Using maximum S_1=15,000 p.s.i. at center:

$$\Delta T_c=\frac{15000\left[\frac{(19.5)(0.87)}{28.5\times10^6}+\frac{(16.5)(0.835)(16.5)(1)}{14\times10^6(19.5)(5)}\right]}{(16.5\times10.4\times10^{-6}-19.5\times5.6\times10^{-6})}$$

$$\Delta T_c=189°\text{ F.}$$

$$\Delta_D=\frac{2\times15000\times19.5\times.87}{28.5\times10^6}+2\times19.5\times5.6\times10^{-6}\times189$$

$$\Delta_D=0.0179+0.0413=0.0592\text{ inch}$$

at end:

$$S_1=\frac{189(18.5\times10.4\times10^{-6}-19.5\times5.6\times10^{-6})}{\frac{19.5\times.87}{28.5\times10^6}+\frac{18.5\times.835}{14\times10^6}\times\frac{18.5\times1}{19.5\times1}}$$

$$S_1=9{,}560\text{ p.s.i.}$$

$$\Delta_D=\frac{2\times9560\times19.5\times.87}{28.5\times10^6}+0.0413$$

$$\Delta_D=0.0114+0.0413=0.0527\text{ inch}$$

$$\text{Crown}=0.0592-0.0527=0.0065\text{ inch}$$

It will thus be seen that a predetermined crown is obtained at a given operating temperature and it is apparent that this crown is varied in response to variations in such operating temperature.

Referring now to FIGURE 3, it will be seen that there is shown a roll structure corresponding in many respects to the roll structure of FIGURE 2, wherein elements comparable to those of the embodiment of FIGURE 2 are indicated by the same reference numeral in the 30 series, i.e. the roll itself is designated by the reference numeral 31 rather than the reference numeral 21 used in FIGURE 2. In the roll 31, however, it will be noted that the inside shell 33 is formed of bronze but it has a substantially uniform thickness or cross-sectional area, whereas the outer shell 32 is formed of stainless steel but has a non-uniform cross-sectional area, with a substantially reduced annular thickness near the central portion 32*a* thereof. In the roll 31, the relatively thinner annular portion 32*a* in the central portion of the outer shell 32 yields in response to increased radial pressure on the inner shell 33 effected by an increase in temperature thereof, so as to obtain a slightly variable operating crown R–31 at the outer periphery of the roll 31. The use of an increased cross-sectional area of the material of greater coefficient of thermal expansion (as in the embodiment of FIGURE 2) will of course result in a more effective and significant variation in the crown than is obtained in the roll 31. The roll 31 is equipped with an additional feature of the invention and that is a heat insulative rubber coating 39 of substantially uniform thickness covering the outer shell 32 and presenting the actual operating or outer peripheral surface 31*a* for the roll 31. The outer cover 39 is suitably formed of rubber or similar material which has a negligible Young's modulus with respect to the structural elements 32, 33 of the roll 31, but which may function advantageously to con-

trol the temperature of the shell elements 32, 33 and, therefore, the crown R–31.

In FIGURE 4, wherein elements comparable to those shown in FIGURES 2 and 3 are indicated by the same reference numeral in the 40 series, it will be seen that a roll indicated generally by the reference numeral 41, likewise, comprises an outer shell 42 and an inner shell 43. In this instance the outer shell 42 has a reduced thickness at its central portion 42*a* to be contoured to suit the desired crown R–41 within the operating range for the crown. Likewise, the inner shell 43 is provided with an enlarged cross-sectional area at the central portion 43*a* thereof. The contours of the two shells 42 and 43 are made to suit the desired crown (permitting, of course, variations therein as a result of variations in the temperature of the inner shell 43). The resulting annular space 50 between the shells 42 and 43 is filled with a material having a high bulk modulus of elasticity such as sulfur, lead, epoxy resin, or the like. This arrangement permits the force of expansion of the inner bronze shell 43 to be transmitted directly and radially from the shell 43 to the shell 42. As in the case of the roll 21, the greater cross-sectional area at the central portion 43*a* of the inner shell 43 results in a proportionately greater increase in the operating crown R–41 with increases in temperature. The filler material 50 has an extremely low coefficient of thermal expansion so that it does not have any appreciable effect on this aspect of the roll 41. Also, the filler material 50 is preferably a heat insulative material so that temperature changes exteriorly of the roll 41 will have less effect upon the temperature of the inner shell 43 (and, therefore, the ultimate crown on the roll 41). In the roll 41 the heat insulative means 50 is again positioned between the inner shell 43 and the operating outer peripheral surface 41*a* of the roll 41.

In order to obtain significant differences in crown in accordance with the practice of the instant invention, the ratio of outer shell thickness to inner shell thickness may vary from a minimum ratio to from about 1½ to 10 times such minimum ratio (and the ratios of the cross-sectional areas will vary correspondingly, as the squares of the radii of the shells). The outer shell may vary from a practical minimum of about ½ inch in thickness to a practical maximum of about 2 inches in thickness; whereas the inner shell may vary from a practical minimum of about ½ inch in (annular) thickness to a practical maximum of 5 or 10 inches in thickness.

The particular crown obtained in any of such rolls depends upon the foregoing structural features, but also may be varied readily during operation by control of the heat source (S) to effect variations in the temperature of the inner shell and the heat source is equipped with a conventional temperature control device for effectively controlling the temperature of the inner shell and, therefore, the crown.

Roll inner diameter is preferably contoured in accordance with the flexure curve in the manner usually applied in "crowning" the outside diameter of conventional rolls. There is no need, however, for prevision of a finish as in crowning the working, outside, surface. The bore may even be "stepped" i.e., a series of cylindrical bores having diameters successively reduced from ends to center of the roll length such that the steps approximate the desired contour.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

I claim as my invention:

1. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, and means for heating the inner shell, the ratio of cross-sectional area of the inner shell to the outer shell being greater at the center of the roll than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

2. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, and means for heating the inner shell, the outer shell having a substantially uniform cross-sectional area and the inner shell having a substantially greater cross-sectional area in the central portion than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

3. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, and means for heating the inner shell, the outer shell having a substantially smaller cross-sectional area at its middle than at its ends, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

4. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, a filler material between said shells of extremely high bulk modulus of elasticity and extremely low coefficient of thermal expansion, and means for heating the inner shell, the ratio of cross-sectional area of the inner shell to the outer shell being greater at the center of the roll than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

5. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, and means for heating the inner shell, the ratio of cross-sectional area of the inner shell to the outer shell being varied across the width of said shells, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at regions where said ratio is greater than it is at other portions of the shells.

6. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, heat insulative means interposed between the inner shell and the outer periphery of the roll, and means for heating the inner shell, the ratio of cross-sectional area of the inner shell to the outer shell being greater at the center of the roll than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

7. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively

higher coefficient of thermal expansion, heat insulative means covering the outer shell and presenting an outer peripheral surface for said roll, and means for heating the inner shell, the ratio of cross-sectional area of the inner shell to the outer shell being greater at the center of the roll than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

8. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell formed of a material having a relatively low coefficient of thermal expansion, an inner shell rigid with the outer shell and formed of a material having a relatively higher coefficient of thermal expansion, a heat insulative filler material between said shells of extremely high bulk modulus of elasticity and extremely low coefficient of thermal expansion, and means for heating the inner shell,

the ratio of cross-sectional area of the inner shell to the outer shell being greater at the center of the roll than at the ends thereof, whereby heating of said inner shell effects maintenance of a greater outer peripheral dimension for the outer shell at the center than at the ends thereof.

9. A roll whose axis is subject to deflection in response to a load applied to the roll, said roll comprising an outer shell and an inner shell rigid therewith, one of said shells having a substantially higher coefficient of thermal expansion than the other, and means for heating said one of said shells, the ratio of cross-sectional area of the inner shell to that of the outer shell being varied substantially across the width of said shells, whereby heating of said one of said shells effects maintenance of a greater outer peripheral dimension.

No references cited.