United States Patent

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[54] **ROLLING MILLS**

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[63] Continuation of Ser. No. 845,819, July 29, 1969, abandoned.

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.**..**72/10,** 72/111

[51] **Int. Cl.** **B21b 37/00**

[58] **Field of Search**.........72/29, 86, 87, 111, 107, 10

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[57] **ABSTRACT**

A four-roll ring rolling apparatus with a pair of rolls for rolling the two curved ring faces and a pair of conical rolls which roll the radial faces of the ring and can be displaced in relation to the ring radially. One roll of each pair of rollers can be fed towards the other radially. At least one roll of each roll pair can be driven. The conical roll pair of rolls is arranged to be automatically displaced in accordance with the increase in the external diameter of the ring owing to the displacement of a feeler roller or the like sensing this diameter at a position adjacent to the pair of rolls, so that it always acts on the radial ring face. The speed of the displacement drive for the conical-roll pair is controlled so as to correspond at least approximately to the speed of increase in ring or hoop diameter. The speed of rotation of the conical-roll pair should be capable of being changed in accordance with the movement of the ring or hoop in relation to the conical rolls in a stepless manner.

9 Claims, 7 Drawing Figures

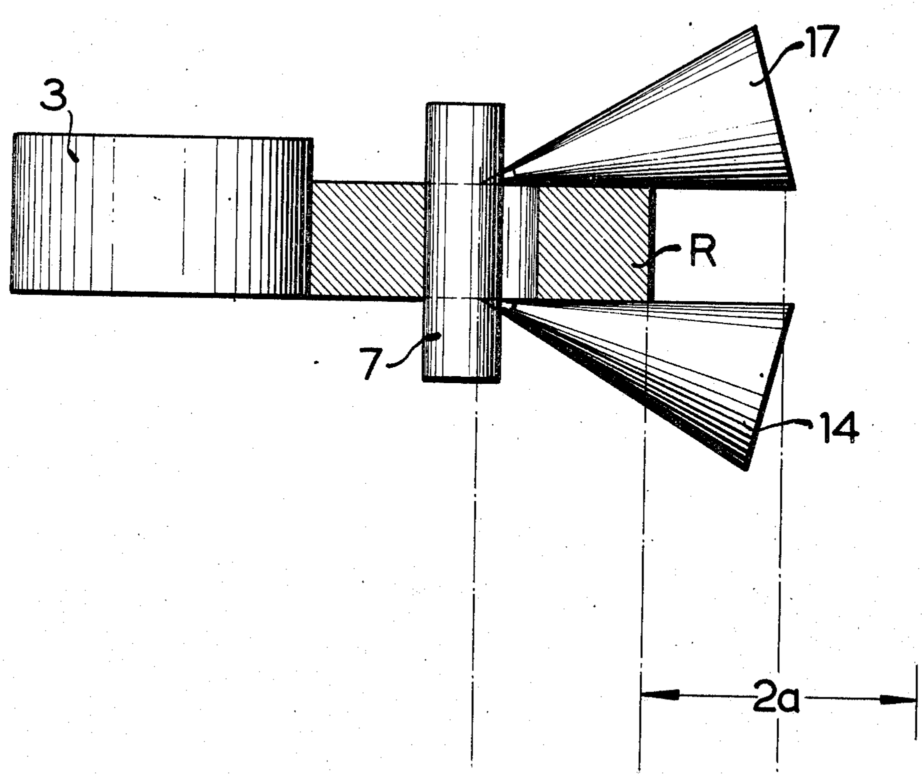

FIG.1

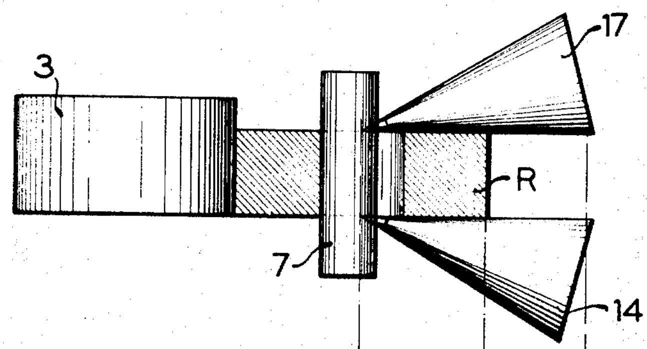

FIG.2

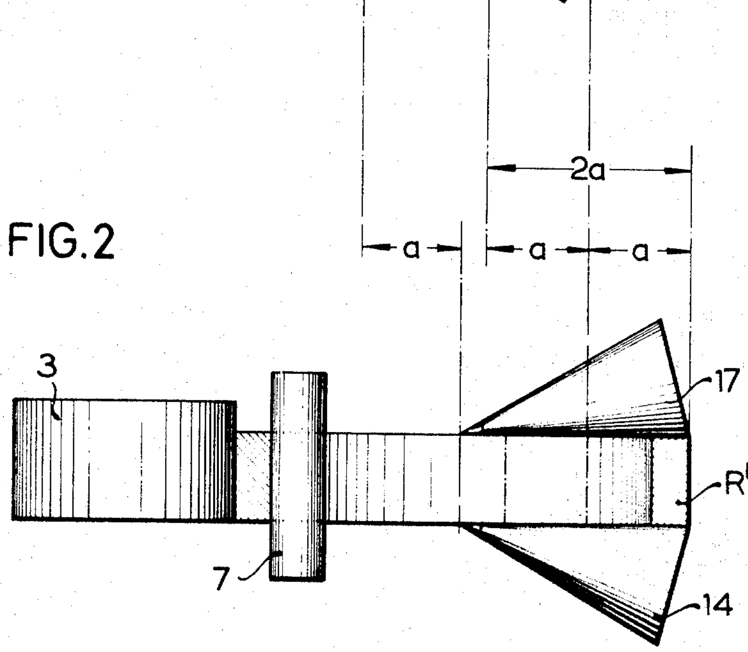

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FIG. 3

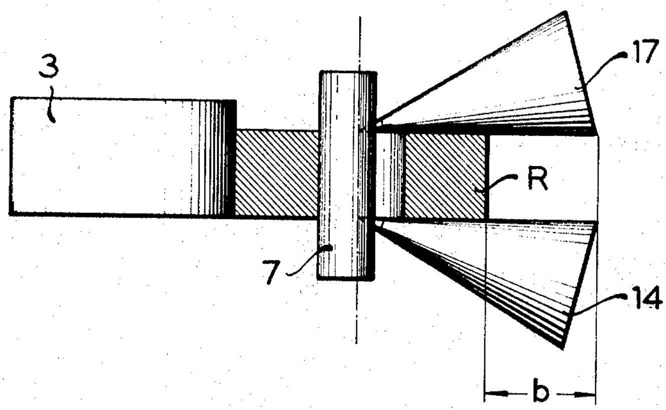
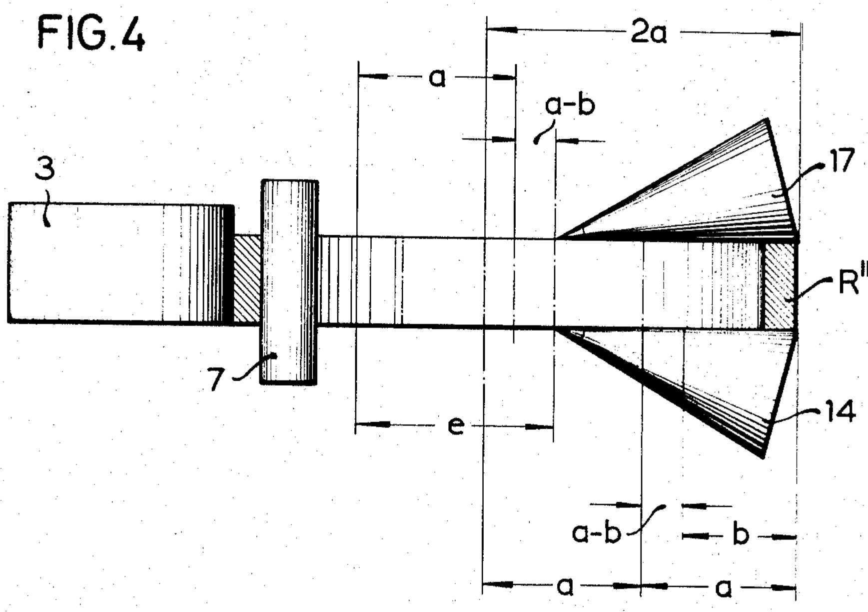


FIG. 4



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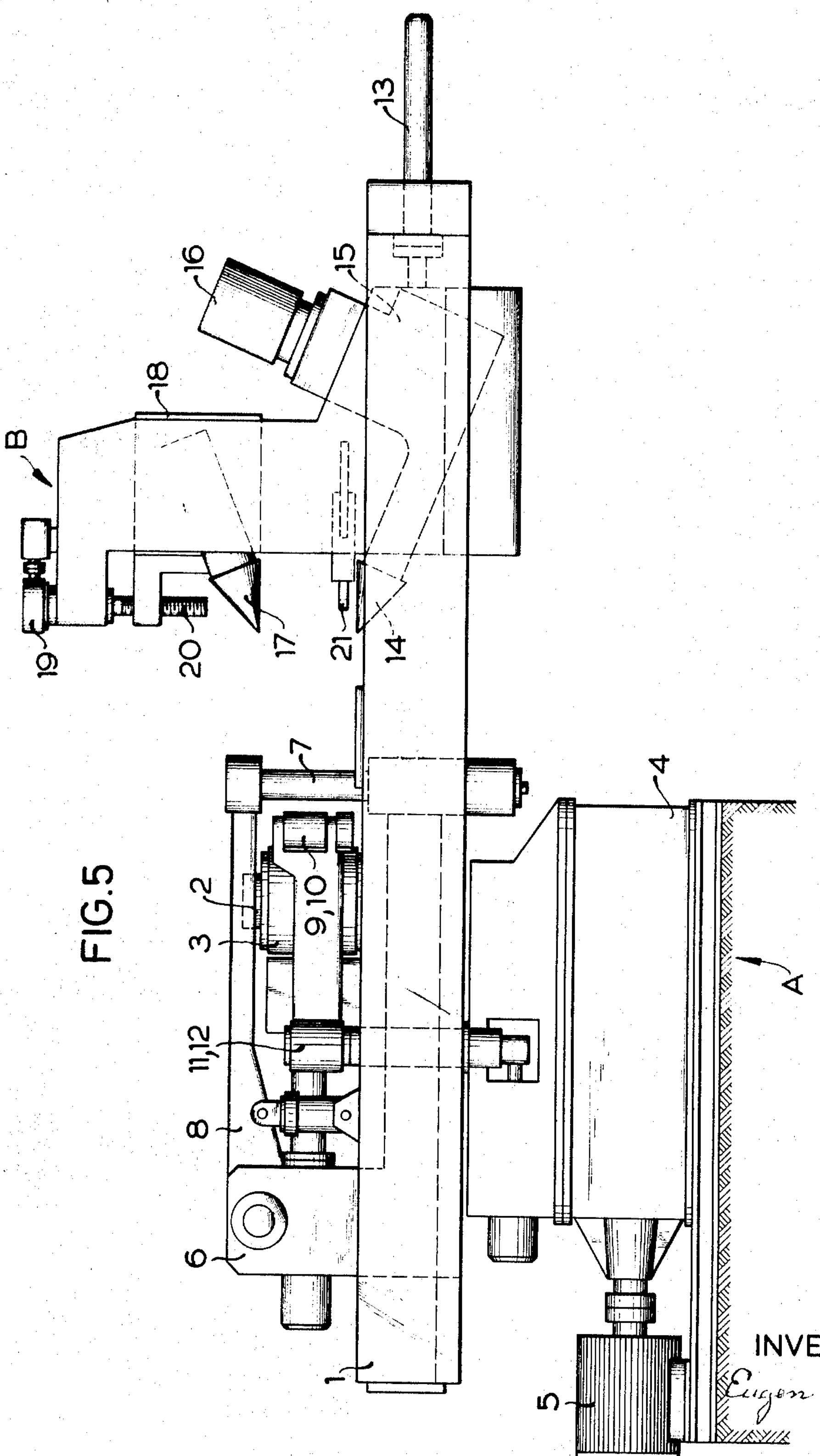

FIG.5

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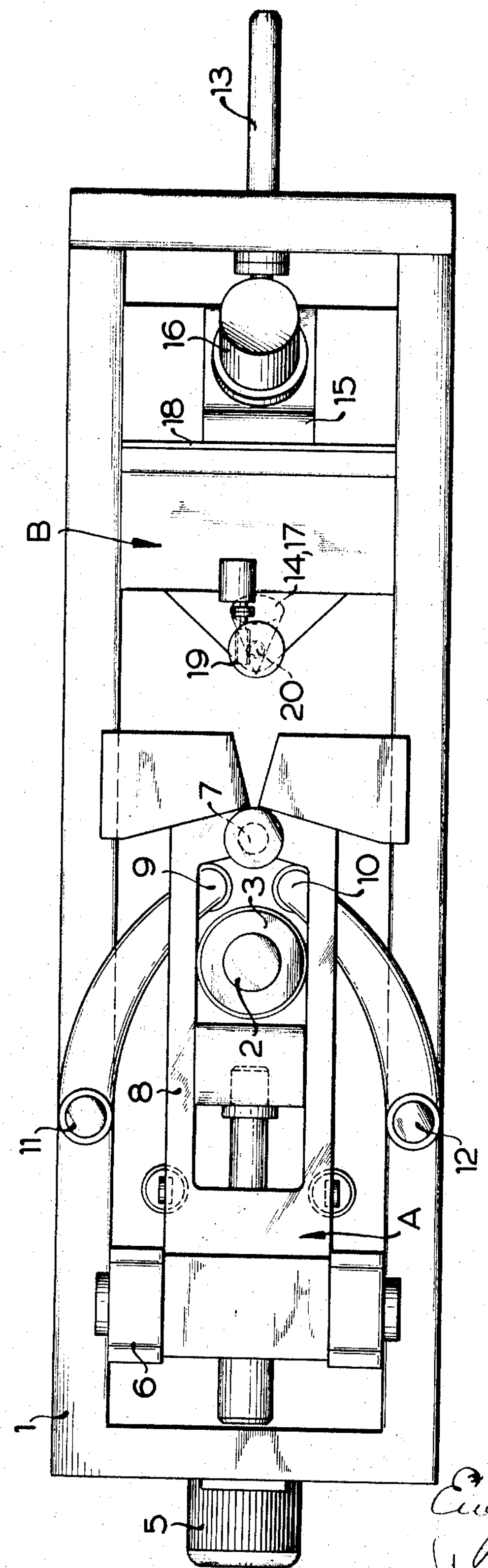

FIG. 6

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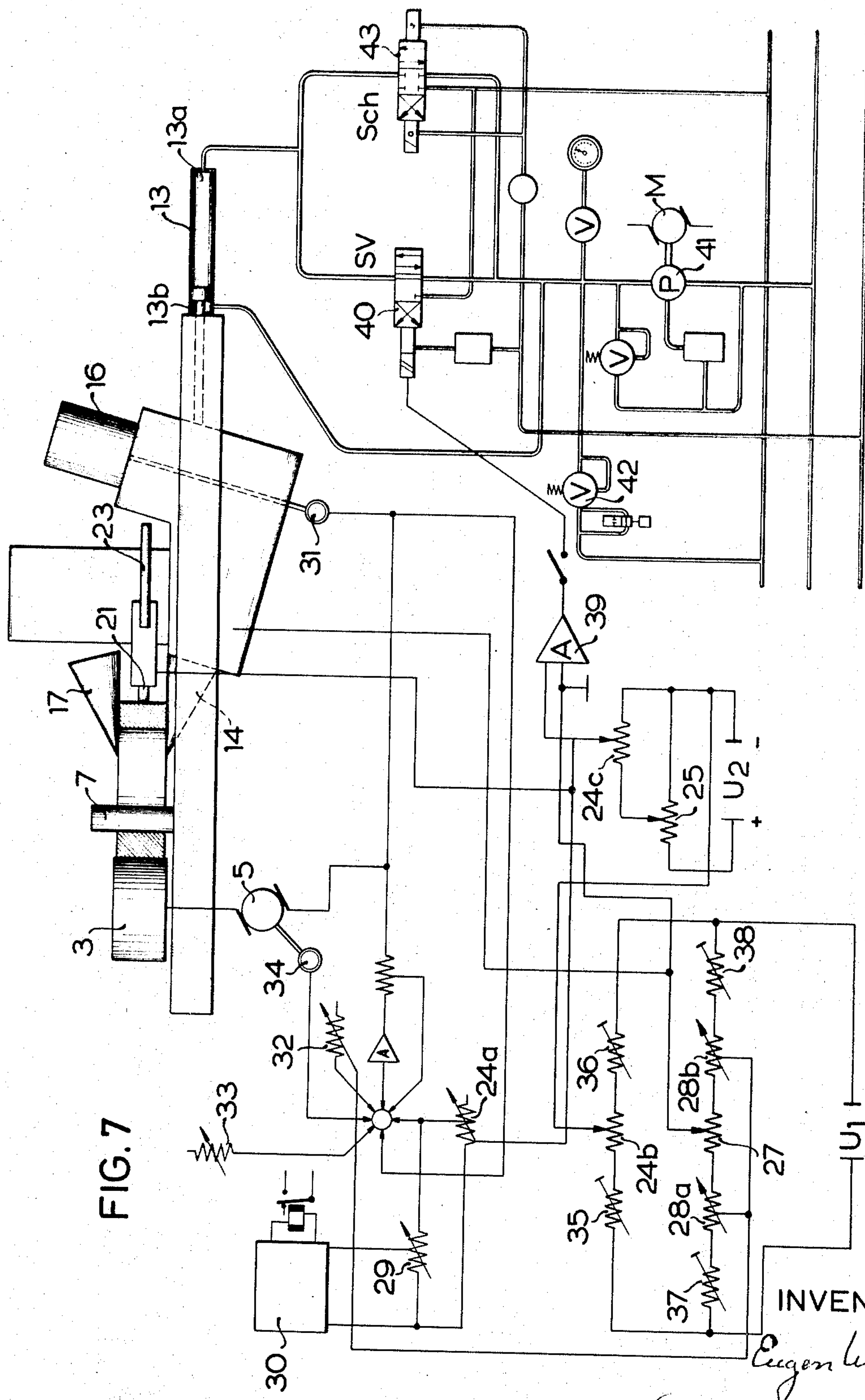

FIG. 7

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ROLLING MILLS

The present invention relates to rolling mills and more particularly to four-roll ring or hoop rolling mills with a pair of rolls rolling the two curved ring faces and a pair of conical rolls rolling the radial ring or hoop faces.

For the production of rings or hoops, blanks can be made in a press or under a hammer from billets by upsetting, perforating and pre-broadening. The blanks are made into rings by radial widening in such four-roll ring rolling mills so that the rolls taken on a rectangular cross section or the cross section of a girder. The radial broadening out of the ring is brought about by the radial roll pair rolling on the two curved ring faces. The radial roll pair comprises a plate roll which is driven and a roll mandril which can be displaced towards the plate roll in order to adjust the rolling force. The axial rolls engaging the radial faces of the ring serve to achieve the required dimension of the ring in the axial direction and to remove the distortion of the radial ring or hoop faces occurring during rolling. The German specification Pat. No. 1,188,544 is concerned with the aim of providing a ring or hoop rolling mill with which rings of different dimensions can be made with a substantial deformation by rolling of the workpiece in the radial direction and, more particularly, in the axial direction. The apparatus is intended to make possible the economic working in accordance with universal rolling programs while achieving a substantial deformation by rolling in the axial and radial directions with a high degree of accuracy and standards as regards the shape of the ring or hoop produced.

The improved system is used in a ring rolling mill comprising a pair of rolls for working the two curved ring faces of a ring and a second pair of rolls rolling the radial faces of the ring and capable of being displaced radially in relation to the ring. One roll of each pair of rolls is capable of being adjusted radially in relation to the other. At least one roll of each pair of rolls is driven. The second pair of rolls is arranged to be automatically displaced in accordance with the increase in the external diameter (by which term is meant the outer diameter) of the ring owing to the displacement of a feeler roller or the like sensing this diameter at a position adjacent to the pair of rolls, so that it always acts on the radial ring face. This problem is solved by provision of a second roll pair consisting of conical rolls and by provision of a displacement system for the second roll pair with controls, which may be electric, hydraulic, etc, including a feeler roll, for displacing the second roll pair back toward the original relative position of the conical rolls and the outer diameter of the ring.

The present invention also has the object of keeping the slip between the conical rolls and the ring as low as possible. The invention, however, makes use of a completely different principle, base on the following considerations.

Roll slip, that is to say the relative displacement between the axial conical rolls and the radial faces of the ring to be rolled out is, providing there are the same peripheral speeds at the plate rolls and at the conical rolls running against the exterior diameter of the ring, equal to zero as long as the points of the conical rolls coincide with the axis of the ring to be rolled. This corresponds to the precise meshing of two bevel gears.

If now the ring is rolled so as to be thinner against the plate roll by feeding the roll mandril, the exterior diameter of the ring increases twice as fast as the axis of the ring moves away.

From this condition results one part of the present invention to the effect that the speed of the displacement drive of the conical rolls is controlled so as to correspond at least approximately to half the speed of increase in ring or hoop diameter.

Such a control arrangement is possible as long as the ring remains within the longitudinal extent of the conical rolls, that is to say as long as the external diameter of the finished ring does not exceed twice the slant height from base to imaginary geometric vertex of the conical rolls, hereinafter called the enveloping length of the rolls.

In order to be able to make use of this principle also in the case of larger rings, a compromise must be made. In accordance with one feature of the invention the displacement of the conical roll pair is chosen so as to be equal to half the increase of the external diameter of the ring plus the difference between half the increase in the ring size and the increase in the ring size between the conical rolls.

Since the speed of rolling at the plate roll remains constant, in accordance with a further feature of the invention the speed of rotation of the conical roll pair should be capable of being changed in accordance with the movement of the ring or hoop in relation to the conical rolls in a stepless manner.

The invention therefore takes as a basis a four-roll ring or hoop rolling apparatus with a pair of rolls for rolling the two curved ring faces and a pair of conical rolls which roll the radial faces of the ring and can be displaced in relation to the ring radially. One roll of each pair of rollers can be fed towards the other radially. At least one roll of each roll pair can be driven. The conical-roll pair of rolls is arranged to be automatically displaced in accordance with the increase in the external diameter of the ring owing to the displacement of a feeler roller or the like which senses this diameter at a position adjacent to the pair of rolls, so that it always acts on the radial ring face. The speed of the displacement drive for the conical-roll pair is controlled so as to correspond at least approximately to half the speed of increase in ring or hoop diameter. The speed of rotation of the conical-roll pair should be capable of being changed in accordance with the movement of the ring or hoop in relation to the conical rolls in a stepless manner.

For the rolling of larger rings or hoops, there is the principle that the displacement of the conical roll pair is chosen so as to be equal to half the increase of the external diameter of the ring plus the difference between half the increase in the ring size and the increase in the ring size between the conical rolls.

In the case of the construction in accordance with the German specification Pat. No. 1,188,544, the reverse speed of the displacement drive for the conical-roll pair was matched so as to agree exactly with the increase in the diameter of the ring or hoop. In accordance with the present invention, the return or reverse speed of this displacement drive is only so regulated that the radial faces of the ring remain in engagement with the conical rolls, without a precise or relatively precise position in relation to the conical rolls being maintained. Instead a displacement of the radial faces of the ring over the enveloping faces of the conical rolls is intentionally allowed. In order to avoid excessive slip, the speed of rotation of the conical rolls is automatically regulated in a stepless manner.

The use of this principle provides a series of advantages.

By fixing the relative position between the conical rolls and the ring there is a comparatively high degree of wear of the conical rolls in those parts on which the contact between the conical rolls and the radial faces is located, while the part of the conical rolls which is not fixed in its relationship to the radial face is only slightly worn or not worn at all. This leads to a local and premature wear of the conical rolls. But when the principle of the present invention is used, the conical rolls are worn over their whole enveloping faces practically constantly. Thus a longer period of service life of the conical rolls is to be expected.

Since, in accordance with the principle of the present invention, at the beginning of the rolling procedure the conical rolls engage radial faces of the ring with their small-diameter zones, they must be run at a higher speed, whereby, at the beginning of rolling, the greater power of the drive motor is used in a rational manner.

The use of the small-diameter zones of the conical rolls at the beginning of the rolling procedure furthermore brings with it the advantage that because of the smaller radius of curvature at these positions of the conical rolls, the specific rolling pressure on the radial faces of the ring is greater. That is to say, for a given rolling force, the rolling action is greater at the beginning of the rolling procedure.

An important feature which can be adopted in a rolling apparatus or mill in accordance with the invention is that, during rolling procedure, the displacement drive for the conical roll pair, and therefore the pair itself, is only driven with half, or approximately half, the speed with which the increasing outer diameter of the ring grows in the slide direction of this roll pair.

Thus, if before the beginning of the rolling procedure, this conical roll pair had a position which was ideal as regards freedom from slip, that is to say so that the imaginary geometrical vertices of the conical rolls lie on the center line of the ring, this ideal position is maintained wholly or at least substantially wholly during the rolling procedure.

Further possible features of the invention, more particularly as regards the control means, are set forth in the claims.

The invention is now described with reference to the accompanying drawings in more detail.

FIG. 1 shows the rolling of small rings or hoops, the apparatus being in the position corresponding to the beginning of rolling procedure.

FIG. 2 shows the rolling of small rings, the apparatus being shown in the position assumed at the end of the rolling procedure.

FIG. 3 shows the rolling of a large ring, the apparatus being shown in the position assumed at the beginning of the rolling procedure.

FIG. 4 shows the rolling of a large ring, the apparatus being shown in the position assumed at the end of the rolling procedure.

FIG. 5 shows a rolling mill or apparatus in accordance with the invention in side view.

FIG. 6 is a plan view of the rolling apparatus in accordance with FIG. 5.

FIG. 7 shows the electrical and hydraulic circuitry for the control or operation of a rolling mill in accordance with the invention.

In FIGS. 1 to 4, corresponding to the symbols used in FIGS. 5 to 7, reference numeral 3 denotes the plate roll, reference numeral 7 denotes the roll mandril, reference numeral 17 denotes the upper, non-driven conical roll and reference numeral 14 denotes the lower, driven conical roll.

FIG. 1 shows the initial position at the beginning of rolling of a ring blank R, which has been placed over the roll mandril 7, and is pressed by the latter against the rotating plate roll 3. The conical rolls 14 and 17 roll against the radial faces of the ring R. Ring R is arranged between the front parts of the conical rolls 14 and 17, and has a smaller diameter at the beginning of the rolling process.

During the course of rolling, the end faces of the ring R are displaced along the enveloping faces of the two conical rolls 14 and 17, the ring blank finally being rolled out to produce the ring R′ as shown in FIG. 2. The radial faces move along the engaging faces of the conical rolls 14 and 17. Care should be taken to see that the tips of the cones, or more precisely, the geometric vertex of the illustrated conical frustum of each roll, always lie against the center axis of the ring. As can be seen by comparing FIGS. 1 and 2, this center axis moves an amount a outwards. It is possible to see from FIG. 2 that the tips of the cones always lie on this center axis. When rolling a ring with this ring diameter, that is to say as long as the ring diameter is equal to or less than twice the length of the enveloping surface of the conical rolls, there is no relative slip between the inner and outer diameters and the conical rolls. An additional factor is that, owing to the movement of the radial faces of the ring R, R′ over the enveloping faces of the conical rolls 14, 17, the latter are evenly worn.

FIGS. 3 and 4 show that the principle of the invention can also be used for the rolling of ring blanks R to rings R″, in which the external diameter of the finished ring exceeds twice the length of the enveloping surfaces of the conical rolls.

The movement of the conical rolls 14 and 17 and the increase in the size of the ring are so matched that, at the end of the rolling procedure, the outer circumference of the ring substantially lies against the outer edges of the conical rolls 14 and 17. The displacement of the conical roll is then equal to half the increment $2a$ in the external ring diameter plus the difference $a - b$, a being half the increase in size of the ring and b being the increase in dimension in the ring between the conical rolls 14 and 17.

Since the rolling speed on the plate roll 3 remains constant, it is naturally necessary, in accordance with a feature of the invention, for the speed of rotation of the conical rolls 14 and 17 to be regulated steplessly, while controlling the movement of the conical rolls 14 and 17, since the ring continuously changes its position between the conical rolls as can be seen from the above explanations. The speed regulation of the conical rolls can either be carried out via a steplessly operating regulating gear drive or by means of a motor whose speed can be regulated. In the case of rings with large diameters as well, one obtains a comparatively small relative slip between the outer and inner ring diameters and the conical rolls.

In accordance with FIGS. 5 and 6, the rolling apparatus or mill can be seen to comprise the horizontal rolling stand A and the vertical upsetting or deforming stand B. The king pin 2 with the plate roll is journalled in the frame 1 common to both parts of the apparatus and is driven via a transmission 4 by an electric motor 5. The roll mandril 7, which is not driven, is mounted in a slide 6 or carriage which is moved hydraulically in relation to the plate roll. The roll mandril 7 is supported at its upper end by means of the frame-shaped holding device 8 which can be swung upwards and lowered hydraulically. At a position adjacent to the plate roll 3, the guide rolls 9 and 10 are mounted, and they are pivoted about the shafts 11 and 12 of a hydraulic cylinder for movement of them apart for movement towards the ring to be rolled. These guide rolls 9 and 10, with their shafts 11 and 12, can be seen in FIG. 6. On the other side of the roll mandril 7, the upsetting frame B can be seen on the roll frame. It is mounted by means which allows sliding. The sliding movement is brought about by a double acting hydraulic cylinder 13. In the bottom part of the upsetting stand or frame B, the lower conical roll 14 is journalled about a fixed axis. It is driven via a stationary gear box 15 by a DC motor 16. The gearbox and the motor are so constructed that the speed of rotation of the conical roll 14 can be so regulated that the peripheral speed of this conical roll can be matched steplessly with the speed of rolling of the plate roll over the whole length of the enveloping surface of the roll.

The upper conical roll 17 is mounted so that it can rotate freely in a carriage or slide 18, which can be moved for setting by means of a motor N (not shown in detail) acting through a worm drive 19 and a lead screw 20. Besides this adjustment, there is also the possibility of lowering the slide 18 further downwards hydraulically, for example by about 50 mm so as to exert a force on the ring to be rolled in the axial direction.

Between the conical rolls 14 and 17, the sensing or feeler roll 21 is mounted. It is attached to a rack, which is loaded by a hydraulic piston 23 (see also FIG. 7) maintained under constant pressure so that the rack is constantly urged into its advanced, terminal position. The ring, which increases in diameter during rolling, presses the sensing roll 21 in a direction corresponding to greater diameter of conical rolls 14 and 17. During this movement the rack actuates a ring potentiometer 24 (*a*, *b*, and *c*) with three tracks 24*a*, 24*b* and 24*c*. The first track 24a provides an input control signal for the drive motor 16 of the lower conical roll 14. The second track 24b provides the input control signal for the movement of the axial frame or stand B. In the case of rings with a diameter which is greater than twice the length of the enveloping surfaces of the conical rolls 14 and 17, the track 24*c* of the ring potentiometer 24 provides an input control signal correction for the movement of upsetting frame B, whereby the ring moves continuously during the rolling procedure over the whole enveloping surface of the conical rolls 14 and 17. When the required ring diameter is attained, the sensing roll is in its retracted terminal position and the rolling procedure is stopped. As has already been mentioned, optimum slip conditions are thereby obtained for the rolling procedure as regards contact between the outer and inner diameters of the ring and the conical rolls. The required external diameter of the roll is preselected at a control console by setting the potentiometer 25, the potentiometer 29 being at the upper abutment.

In the frame 1 of the rolling frame there is a further rack which sets or actuates a ring potentiometer 27 which provides the input control signal for the setting of the axial stand B in relation to the axis of the plate roll 3. The further double potentiometer 28 serves for setting the respective diameter of the plate roll 3. This setting is necessary because the plate roll is subject to wear; therefore, for precise regulation of the whole rolling apparatus, the instantaneous valve of the diameter of the plate roll must be suitably determined and taken into account in setting the apparatus.

The potentiometer 29, with the measuring relay 30, is the switching-off point for the termination of the rolling procedure by the preselection of the setting of the sensing or feeler roll 21 between the conical rolls 14 and 17.

In the case of ring diameters not greater than twice the length of the enveloping surfaces of the conical rolls 14 and 17, the potentiometer 25 is set at the lower abutment. In this case the ring diameter is set by the potentiometer 29.

Since the ring during rolling moves evenly over the whole length of the conical rolls 14 and 17 and the speeds of rolling on the plate roll 3 on the one hand and on the conical roll 14 on the other must be equal in order to preserve the circular shape of the ring, the speed of rotation of the conical roll 14 must be changed steplessly in accordance with the instantaneous position of the ring between the conical rolls 14 and 17.

For this purpose the motor 16 of the axial stand B is supplied with the following input control signals:

a. the setting of the feeler roll 21 and thus of the diameter of the conical rolls, by means of the potentiometer track 24*a;*

b. the output speed of rotation signal of the main motor 5 via the tachometer generator 34.

Thus any change in diameter of the plate roll 3 is fed by the potentiometer 32, which is mechanically coupled with the potentiometer 28, as a correction value or signal into the regulating system. Furthermore the change in the diameters of the conical rolls 14 and 17, which is due to trueing the conical rolls when they become worn, is fed as a further correction value by the potentiometer 33. The output signal in respect of the speed of rotation of the motor 16 is measured by the tachometer generator 31.

The adjustment of the axial stand B is, in principle, an electro-hydraulic following regulation system. A Wheatstone bridge, consisting of the resistors 35, 24b, and 36 in one limb and the resistors 37, 28*a*, 27, 28*b* and 38 in another limb is brought out of balance by the response of the feeler roll 21. The voltage resulting in the null branch between 24b and 27 is evaluated by a null amplifier 39. The output voltage of the null amplifier 39 actuates an electrically operated hydraulic servo value 40 which moves the axial stand B until the Wheatstone bridge is again brought into balance by the potentiometer 27. In the case of rings which are greater than twice the length of the enveloping surfaces of the conical rolls **14** and **17**, the voltage is added to the input voltage of the null amplifier, which is dependent upon the diameter of the finished ring fed in via the potentiometer **25** and supplied in accordance with the position of the feeler roller **21** between the conical rolls **14** and **17** via the potentiometer **24***c*. This added voltage causes the axial stand B to have to move a distance greater than the travel of the sensing roll **21** in order to bring the Wheatstone bridge into balance.

The movement of the axial stand B is brought about by a differential hydraulic cylinder **13** with a piston space **13***a* and an annular space **13***b*. The cylinder receives oil from the pump **41** which, when the axial stand B is stationary, circulates freely via the safety valve **42**. On movement of the axial stand B towards the roll mandril **7** at the beginning of rolling procedure, this valve **42** is closed and the solenoid valve **43** is brought into the right-hand position so that the pumps oil into the piston space **13***a* and oil also passes from **13***b* into **13***a*. On movement of the axial stand away from the roll mandril **7** at the end of rolling the safety valve **42** is closed again and the solenoid valve **43** returns back into the left-hand position. As a result the pump pumps oil into the space **13***b*, while the space **13***a* is connected with the hydraulic oil container for the free discharge of oil. In the setting for regulation during rolling, the valve **42** is closed and the solenoid valve **43** is in the central position. The pump conveys oil into the space **13***b*. However, hydraulic oil forced out of the piston space **13***a* is controlled via the servo valve **40** and the electrical regulation means in such a manner that the axial stand is moved away from the roll mandril **7** only with the speed determined by the regulation means.

I claim:

1. In a ring rolling machine for rolling an annular ring blank which has a center axis, inner and outer peripheral surfaces, and two axial end faces, wherein the machine comprises:
   A. roller means for engaging and rolling said peripheral surfaces,
   B. a pair of conical rollers for engaging and rolling respectively the two end faces, and
   C. sensing means for mechanically determining the position of said center axis and the corresponding outer radial dimensions of the ring blank, the improvement comprising:
   D. means responsive to the sensing means for displacing said conical rollers at such a rate that the geometrical vertices of the conical rollers remain substantially on said center axis as said radial dimensions increase,

   whereby a substantial portion of the surface of the conical rollers may be used to engage and roll the end faces of rings which remain, at their greatest radius, within the longitudinal extent of the conical rollers, as measured from the geometrical vertices.

2. A machine according to claim **1** wherein said sensing means is a feeler roller for continuously sensing the diameter of the ring blank at a position adjacent to the pair of rolls by feeling the outer peripheral surface.

3. A machine according to claim **2** further comprising:
   A. a first potentiometer means responsive to the feeler roller for supplying a signal representing speed of rotation for use in controlling the drive speed of the conical rollers
   B. a second potentiometer means responsive to the feeler roller for supplying a signal representing ring diameter for use in controlling the displacement drive of the conical rollers

4. In a ring rolling machine for rolling an annular ring blank which has a center axis, inner and outer peripheral surfaces, and two axial end faces, wherein the machine comprises:
   A. roller means for engaging and rolling said peripheral surfaces,
   B. a pair of conical rollers for engaging and rolling respectively the two end faces, and
   C. sensing means for mechanically determining the position of said center axis and the corresponding outer radial dimensions of the ring blank, the improvement comprising
   D. means responsive to the sensing means for displacing said conical rollers at such a rate that the distance between the geometrical vertices of the conical rollers and the center axis remains equal to the difference (a–b) between half the increase in ring size $1/2(2a)$ and the increase (b) in ring size between said conical rollers.

   whereby a substantial portion of the surface of the conical rollers may be used to engage and roll the end faces of rings which, at their greatest longitudinal extent, have a radius which exceeds the engaging length of the conical rolls.

5. A machine according to claim **4** wherein said sensing means is a feeler roller for continuously sensing the diameter of the ring blank at a position adjacent to the pair of rolls by feeling the outer peripheral surface.

6. A machine according to claim **5** further comprising:
   A. a first potentiometer means responsive to the feeler roller for supplying a signal representing speed of rotation for use in controlling the drive speed of the conical rollers
   B. a second potentiometer means responsive to the feeler roller for supplying a signal representing ring diameter for use in controlling the displacement drive of the conical rollers.

7. A machine according to claim **6** further comprising:

   a third potentiometer means responsive to the feeler roller for supplying a correction signal for controlling the displacement drive of the conical rollers.

8. A machine according to claim **6** further comprising:
   A. a tachometer means for supplying a signal proportional to the speed of rotation of said conical rollers, and
   B. rotational drive means for said conical rollers responsive to said signal proportional to the speed of rotation of said conical rollers and to said signal representing speed of rotation for feedback control of said drive means.

9. A machine according to claim **3** further comprising:
   A. a tachometer means for supplying a signal proportional to the speed of rotation of said conical rollers, and
   B. rotational drive means for said conical rollers responsive to said signal proportional to the speed of rotation of said conical rollers and to said signal

representing speed of rotation for feedback control of said drive means.

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