

- [54] **ROLLING MACHINES**  
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- [63] Continuation-in-part of Ser. No. 102,380, Dec. 29, 1970, abandoned.

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[51] **Int. Cl.** ..... **B21h 1/12**  
[58] **Field of Search** ..... **72/366, 102, 107, 108,**  
**72/110; 29/148.4 R**

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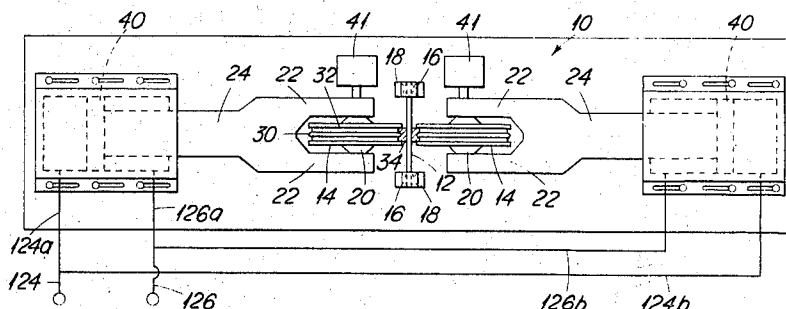
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*Attorney, Agent, or Firm*—Cushman, Darby & Cushman

[57] **ABSTRACT**

This invention relates to improvements in rolling machines and methods of forming initially cylindrical workpieces to shape. The workpiece is initially located along its axis relative a pair of forming members and then rolled to shape, at least one of which has a profile to be squeezed into the workpiece. The forming member or members having the profile have radially outwardly diverging flanges at their edges to control the shape of the edges of the cylindrical workpiece and determine width-wise spread. Where the workpiece is rotatably fitted over a mandrel and at least two forming members are spaced evenly around the workpiece, a number of rotatably supported growth control rolls are spaced around the workpiece, arranged to remain in contact therewith during rolling in peripheral regions between the forming rolls and prevented from retracting during rolling so avoiding substantially deformation of the workpiece from the circular and preventing undue metal fatigue.

**16 Claims, 9 Drawing Figures**



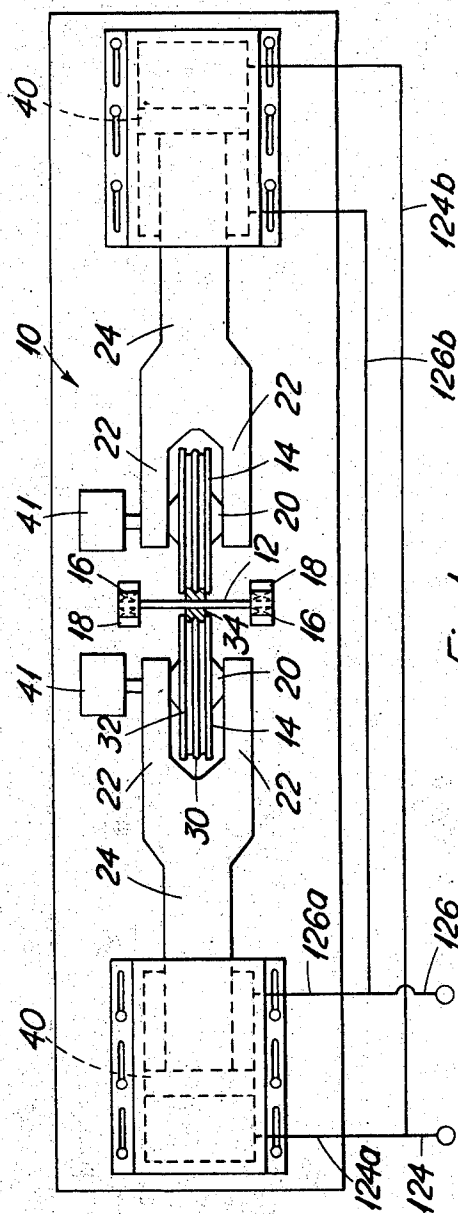
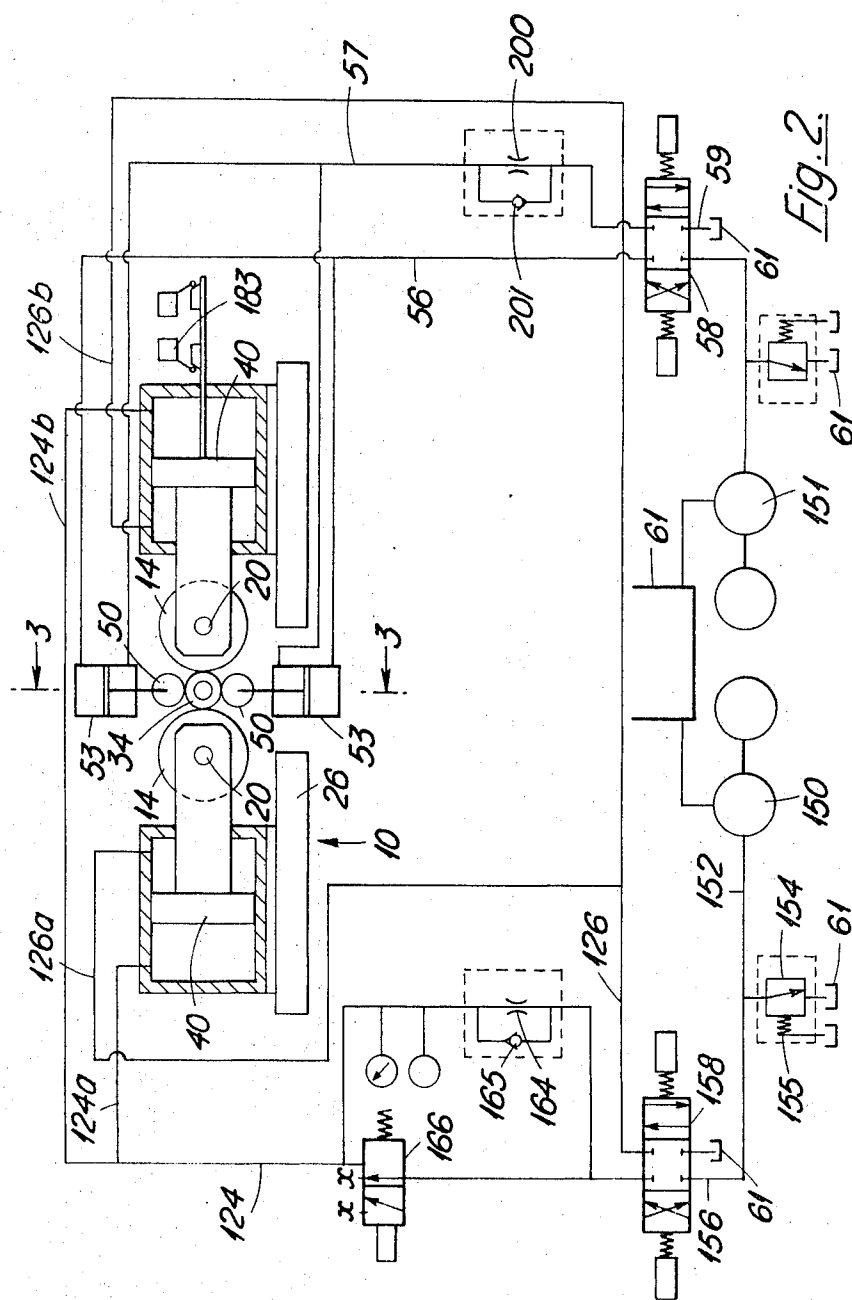
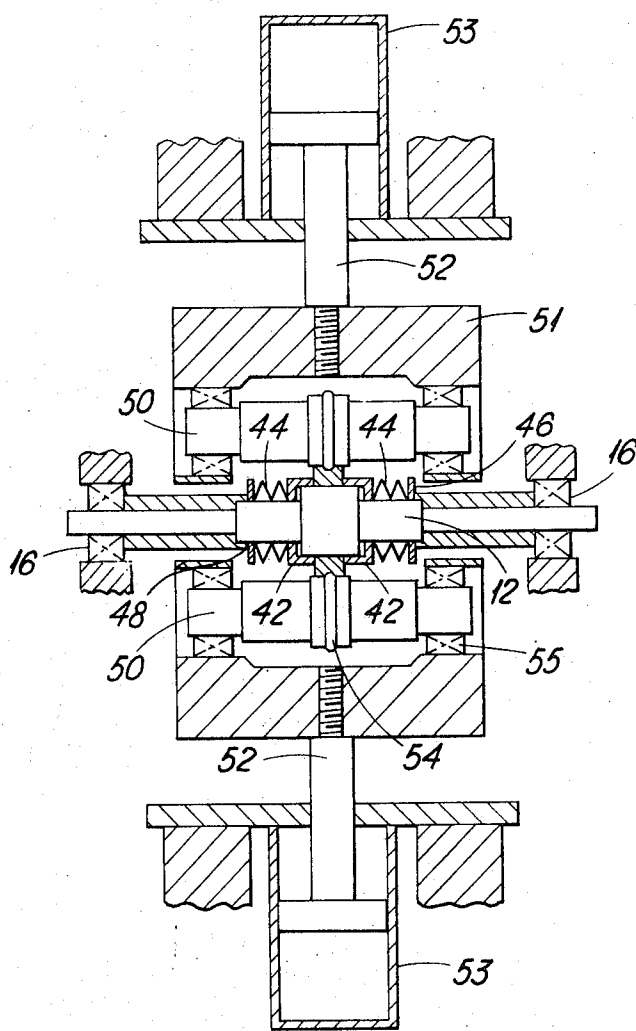


Fig. 1.





*Fig. 3.*

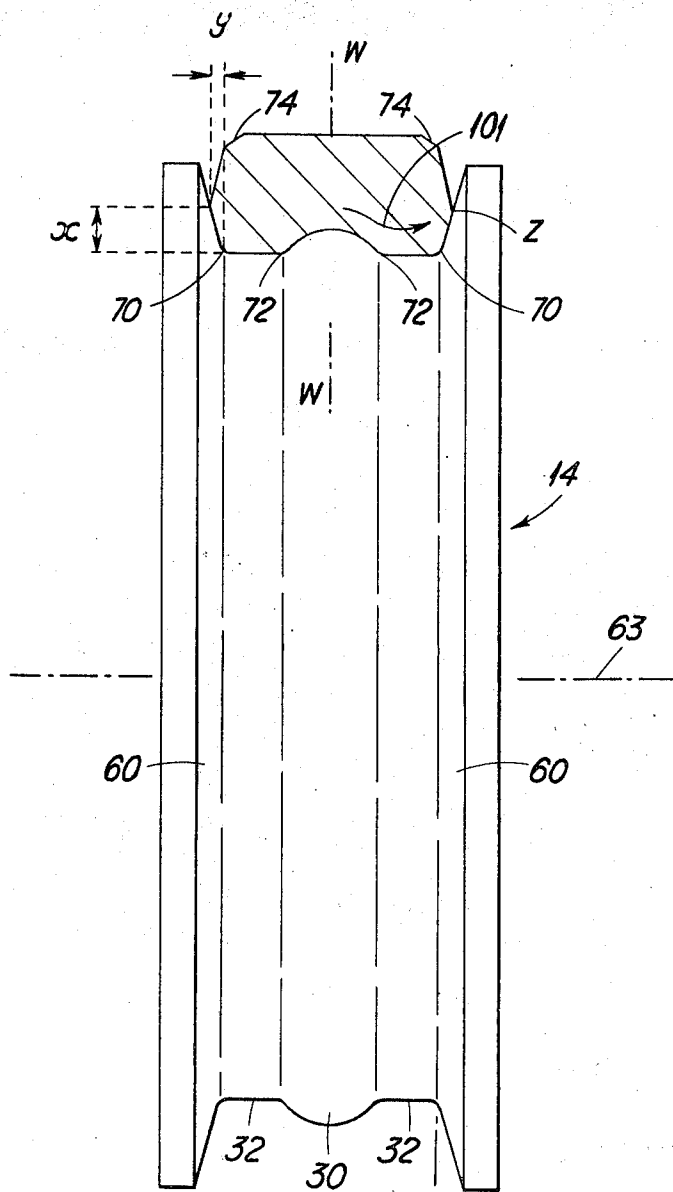


Fig. 4.

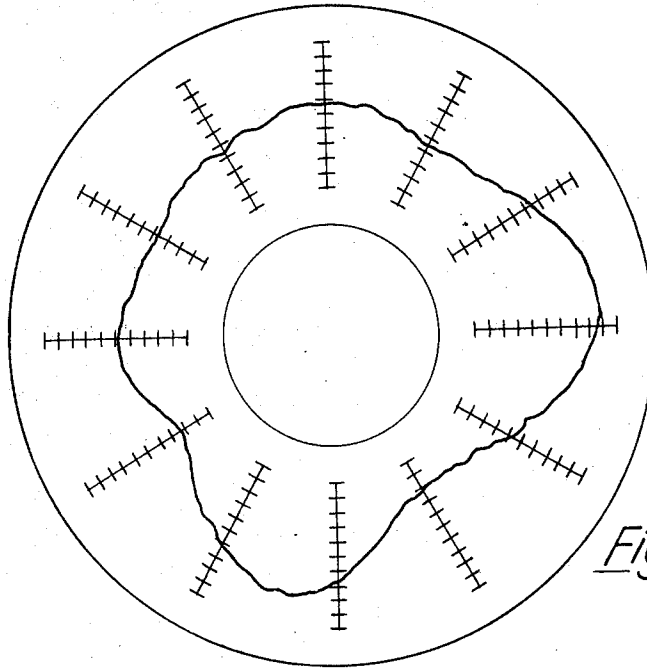


Fig. 5.

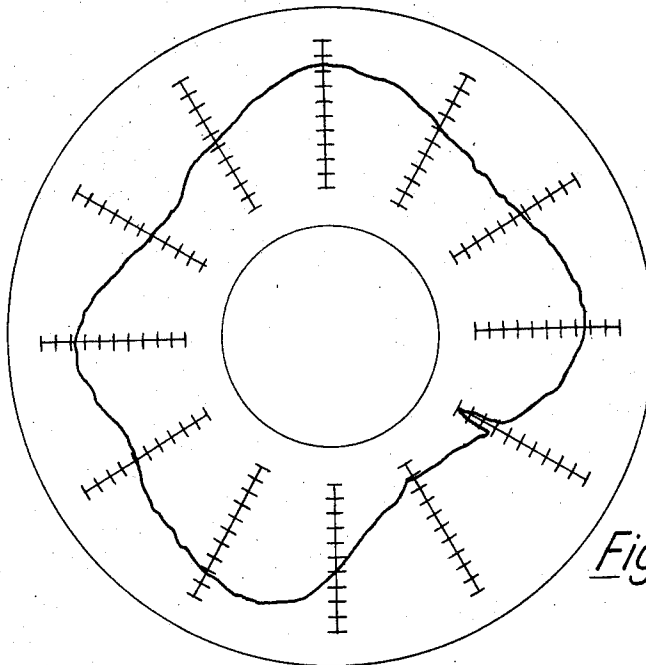


Fig. 6.

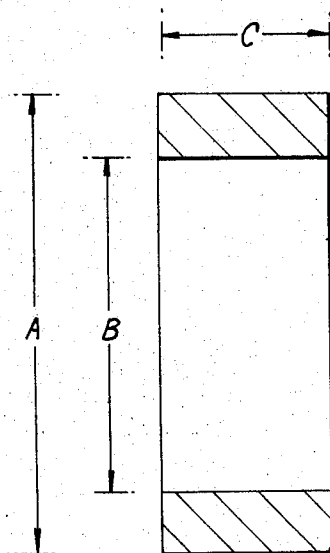


Fig. 7.

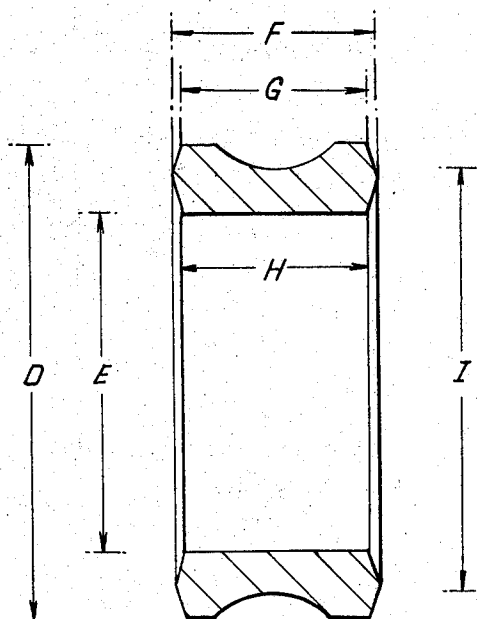
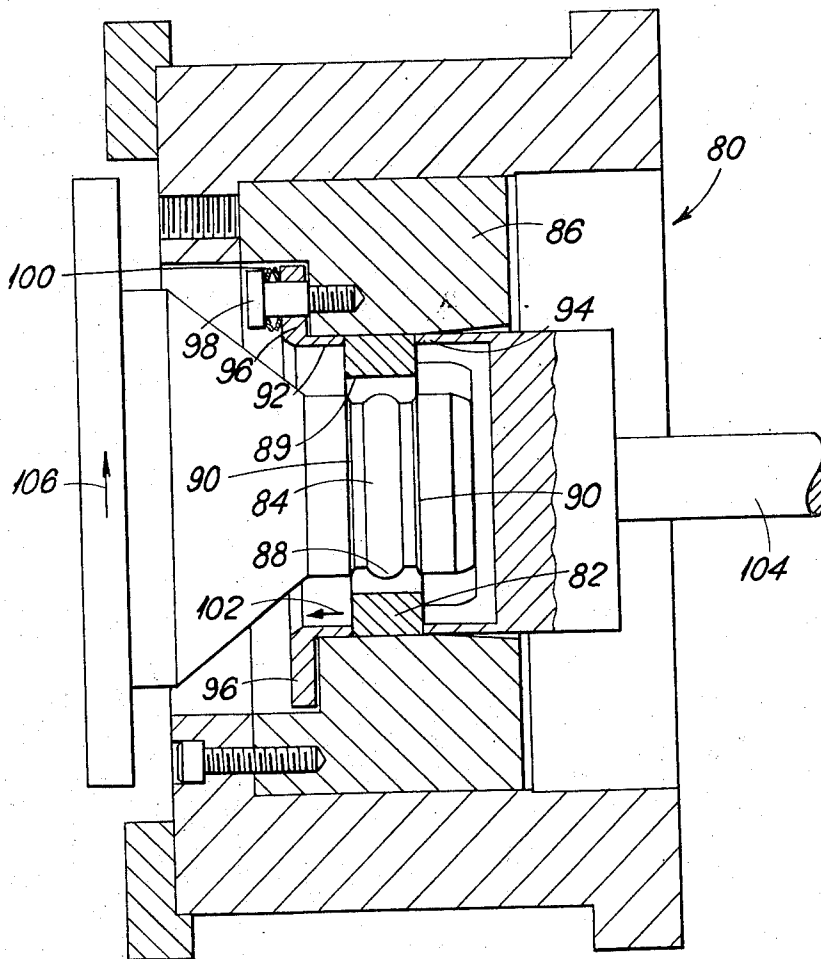


Fig. 8.



*Fig. 9.*

## ROLLING MACHINES

This application is a continuation-in-part of my co-pending application Ser. No. 102,380 filed on Dec. 29, 1970 now abandoned.

This invention relates to improvements in rolling machines and is particularly concerned with machines in which metal workpieces or blanks are formed to shape by being rolled under pressure. In particular the invention relates to rolling machines which are eminently suited for forming bearing rings from plain cylindrical workpieces.

## BACKGROUND OF THE INVENTION

When a workpiece is rolled to shape it is squeezed between two forming members which press into the workpiece a shape dictated by the profile of the forming members. In this way excellent profiled workpieces can be made. It has not been possible, however, to ensure that the profile is consistently positioned on the workpiece with the result that from a production run one can not be sure of achieving a series of rolled workpieces which are identical with one another.

## THE INVENTION

Therefore according to the invention there is provided a method of forming to shape an initially cylindrical workpiece in which the cylindrical workpiece is initially located along its axis relative to a pair of forming members one or both of which are forming rolls having a profile to be squeezed into the workpiece, and is then rolled and squeezed between the pair of forming members to impress in the workpiece the profile, the forming roll or rolls having radially outwardly diverging flanges at their edges which control the shape of the edges of the workpiece and determine the width-wise spread of the workpiece during rolling, and these flanges on the roll or rolls being angled at an angle of up to 15° to the normal to the axis of rotation of the roll.

By angling the flanges at an angle of up to about 15° to the normal to the axis of rotation of the rotation of the roll, this is found to reduce or eliminate scuffing and slivering of the side faces of the workpiece so avoiding small pieces of metal rolling into the surface being rolled, so damaging it. This angling of these flanges also gives a better flow of metal.

By using rolls such as these one can roll workpieces accurately to shape and each rolled workpiece of a production run will be identical with one another since one can ensure that the profile given to the workpiece is accurately positioned relative to the workpiece.

Provided one starts with a cylindrical workpiece of known volume, the side flanges on the roll or rolls control the width-wise spread of the workpiece during rolling and, after filling the width of the profiled roll, the metal in the workpiece flows so as to start to travel up the sides of the flanges. Because these are angled at no more than a small angle to the normal to the axis of rotation of the roll, the final overall width of the rolled workpiece is only dependent to a very small degree upon the extent to which metal has flowed up the side edges of the flanges. The degree of this flow can be controlled fairly accurately by controlling the time of rolling. Therefore the rolled workpiece has an accurately known width and the impressed profile is accurately spaced in relation to the side edges. Therefore,

when effecting any further process steps on the rolled workpiece, e.g., grinding, one can determine the location of the rolled workpiece by means of its side edge and in so doing accurately locate the rolled profile.

Usually the formed workpiece is heat treated and then finally ground to exact size. It is found that, after rolling according to the invention, relatively little distortion of the formed workpiece occurs during this heat treatment, and a smaller amount of material needs to be removed in the ensuing grinding step to give the finished accurate bearing ring than in the case where the bearing ring is formed by conventional machinery followed by grinding.

In addition, because rolling to shape does not involve the removal of material, bearing rings can be made from less stock material as compared with conventional machining to shape.

Bearing rings can therefore be produced more economically according to the invention than by conventional machining.

The workpiece is initially located along its axis in relation to the roll or rolls. This can be achieved for example, quite simply by resiliently holding the workpiece between opposed spring means. The pressure exerted by these spring means then automatically centres the workpiece in relation to the forming roll or rolls and ensures that the width-wise spread of the workpiece is consistent from workpiece to workpiece.

The invention is applicable to the case where a profile is rolled into the outer facing surface of a workpiece in which case the workpiece can be rotatably supported on a mandrel and rolled between, for example, a pair of profiled forming rolls, and also the case where a profile is rolled into the inner facing surface of a workpiece in which case the workpiece is squeezed between an inner profiled forming roll and an outer cylinder.

All corners on the forming part of the forming roll or rolls should have the maximum radius possible to promote better metal flow and prevent trapping of the metal. In addition this is found to reduce the incidence of cracking of the formed workpiece during subsequent heat treatment. The flanges should then desirably lead from these rounded corners at a tangent.

Rolling machines for forming a profile in the outer facing surface of a workpiece, e.g., for forming an inner bearing ring, generally comprises two heads, each of which carries a driven forming roll or die. Between the two heads is mounted a rotatable mandrel over which the workpiece or blank to be formed fits. A workpiece is formed by rotating the rolls and squeezing the workpiece between the forming rolls by relative movement of the heads towards one another.

During rolling it sometimes happens that the workpiece being formed will fracture. This generally occurs when the cross-section of the workpiece is small compared with the size of the form being produced in it, and hence the workpiece is less rigid. The reason for the fracture is believed to be metal fatigue due to distortion of the workpiece from the circular during rolling. As the workpiece is rotating during the squeezing operation there is a tendency for the circumference of the workpiece to grow and because the diametral dimension, measured in line with squeezing force, cannot increase, the diametral dimension measured at 90° to the force line will increase causing ovality in the workpiece. This, therefore, causes the workpiece to change

diametral dimension between these two limits, the number of reversals being dependent on the speed of rotation and the 'in' feed rate of the forming rolls. This causes the ring section to be alternately in compression and tension which can rapidly cause a fatigue fracture.

Therefore with this problem in mind, according to another aspect of the invention there is provided a machine for rolling a workpiece to a desired shape comprising a rotatable mandrel over which the workpiece is to fit so as to be supported by the mandrel during rolling, at least two heads evenly angularly spaced around the periphery of the workpiece, each head being capable of carrying a driven forming roll shaped to roll the workpiece to the desired shape and being constrained so that the rolls are movable relative to the workpiece in a direction radially of the workpiece so that the workpiece is shaped by being squeezed by the forming rolls, location means for initially locating the workpiece along its axis relative to the forming walls, and a number of rotatably supported growth control rolls which are spaced around the workpiece and are arranged to remain in contact with the workpiece during rolling in peripheral regions between the forming rolls and are arranged to be prevented from retracting during rolling so avoiding substantial deformation of the workpiece from the circular and preventing undue metal fatigue.

These growth control rolls contact the workpiece and urge it towards the mandrel in the peripheral regions between the forming rolls so as substantially to prevent deformation of the workpiece becoming oval or other than substantially circular. The growth control rolls must exert a force on the workpiece during which reduces this deformation but at the same time does not significantly form the cross-sectional profile of the workpiece. Instead they should merely follow the forming of the workpiece and restrain it to prevent the metal fatigue described above.

The growth control rolls must be urged against the workpiece by means which prevent their retraction during rolling. They can be advanced, for example, by a screw feed by and preferably urged against the workpiece by hydraulic rams which prevent the growth control rolls from retracting during the rolling process but enable them to maintain contact against the workpiece as the form is produced. We find that the force which the growth control rolls exert on the workpiece should increase during forming up to a maximum. For example, when rolling workpieces up to about 4 inches outside diameter in the material known as EN 31, the maximum force exerted on the workpiece should be about 12,000 lb.

It is preferred that these growth control rolls have a profile which is the same or similar to that on the forming rolls so as to interfere with the forming operation. Preferably the growth control rolls have a profile identical with the forming rolls except that they have no side flanges. In some cases, however, plain cylindrical growth control rolls may be used.

Preferably, the growth control rolls are arranged in opposed pairs or pairs of groups so as not to place any undue stress on the support mandrel. The number of growth control rolls used can vary depending on the size of the workpiece and the number of forming rolls used. In the case where a pair of diametrically opposed heads carry the forming rolls are used, a pair of diamet-

rically opposed growth control rolls can be used which are spaced at 90° to the forming rolls.

According to another aspect of the invention there is provided a process for rolling a workpiece to a desired shape using a machine as defined above in which a process for rolling a workpiece to a desired shape using a machine as claimed in any of claims 8 to 13 in which the workpiece is initially located along its axis by the location means, is then squeezed by the forming rolls sufficiently to indent the workpiece to start the shaping of the workpiece and form a location for the growth control rolls and thereafter the workpiece is contacted by the growth control rolls, the growth control rolls contacting the workpiece with a force sufficient to prevent deformation from the circular between the forming rolls but insufficient to cause substantial forming of the workpiece and, after the workpiece has been rolled to the desired shape, the forming rolls and the growth control rolls all start retracting at the same time.

By following such a process the growth control rolls are able to follow the shaping produced by the forming rolls while not themselves significantly forming of the workpiece. The initial contact of the forming rolls produces some work hardening and so the growth control rolls do not distort or deleteriously affect the shaping of the workpiece. In practice the growth control rolls can contact the workpiece almost immediately after the workpiece has been contacted by the forming rolls.

In order to ensure that the growth control rolls follow shaping produced by the forming rolls, the growth control rolls should be mounted so as to be resiliently movable in a direction along their rotational axes.

Once the forming rolls reach their full forming depth, it is preferred that they remain there for the minimum number of revolutions of the workpiece because longer dwell in that position is found to increase the workpiece diametrical growth and distortion which can cause excessive heating and fracture of the workpiece.

At the ends of the rolling operation both sets of rolls start to retract at the same time. In the case where all of the rolls are urged against the workpiece by hydraulic rams, the timing of this retraction can be initiated by a build-up in pressure in the rams controlling the advancement of the heads. Alternatively, this retraction can be initiated by say, a micro-switch controlled by a timer or by the position of the heads.

The rate at which the forming rolls advance relative to the workpiece should preferably be from 0.010 to 0.020 inch per revolution of the workpiece for workpieces of up to about 4 inches outside diameter.

Normally the machine will have two heads which are positioned opposite one another, the heads preferably being constrained to move towards and away from one another along a path which coincides with a diameter of a workpiece to be rolled so that the forming rolls contact the workpiece during rolling at diametrically opposed portions. In some cases, however, it may be desirable to provide more than two heads, e.g., three heads spaced at 120° to one another around the periphery of the workpiece to be rolled.

The heads are all preferably urged in towards the workpiece during the rolling operation by means of hydraulic rams. A similar ram can be fixed to each head and then by linking all of the rams in parallel to a source of pressurized hydraulic fluid, all of the heads

will move equally and so exert balanced forming pressures on the workpiece and mandrel.

In order to ensure that the heads advance equally during a forming operation they can additionally be linked mechanically. An important advantage of linking the heads mechanically, is that the piston seals of the hydraulic rams can be cheaper and simpler since the mechanical link will constrain the head movements even though there may be slight leakage past these seals. This also avoids frequent replacement of these seals.

The machines of the invention are especially suitable for the production of relatively small articles, i.e., articles having a maximum outside diameter of 3 to 6 inches. In particular, the machines are useful for the production of the inner bearing rings. The invention is not, however, exclusively limited to the production of these and, depending upon the shapes of the forming rolls, gear wheels can, for example, be formed using toothed rolls.

During rolling the forming rolls are rotated. This can suitably be effected by hydraulic motors, one driving each forming roll. This has the advantage that one can rapidly and easily reverse the direction of rotation of the rolls during rollings as is sometimes desirable to give a better rolling surface finish.

In the rolling of an inner bearing ring, one or more annular grooves or recesses are formed in the outer facing surface of an initially cylindrical workpiece. The inner facing of the workpiece does not have to be altered and so the mandrel has a plain cylindrical surface. This plain surface may be formed as part of the mandrel itself or may be a separate cylindrical roll rigidly fixed around a part of the length of the mandrel.

The diameter of the forming roll is dependent on the size of the workpiece but in general one should use a roll having the largest diameter which is practical in any instance. Having chosen the diameter of the forming rolls the diameter of the growth control rolls should then be chosen and be as large as possible.

The rolling of the workpiece can be effected without external heating in which case the rolling is termed cold rolling; or equally the rolling can be effected by pre-heating or externally heating the workpiece during rolling in which case the rolling is termed hot rolling.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Cold rolling machines according to the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

FIG. 1 is a plan view of a cold rolling machine for rolling a profile into the outer facing surface of a cylindrical workpiece;

FIG. 2 is an elevation of the machine shown in FIG. 1 showing additionally a hydraulic circuit used in the operation of the machine;

FIG. 3 is a cross-section taken on the line 3—3 of FIG. 2;

FIG. 4 is an enlarged diagram showing the forming rolls of the machine shown in FIG. 1 and a formed workpiece;

FIGS. 5 and 6 are charts of the deviations of diameter of a typical rolled workpiece prepared on the machine shown in FIG. 1 before and after heat treatment, respectively;

FIG. 7 is an axial section through a workpiece before forming according to the invention;

FIG. 8 is a section similar to FIG. 7 of the workpiece after forming according to the invention; and

FIG. 9 is a sectional elevation detail of a cold rolling machine for rolling a profile onto the inner facing surface of a cylindrical workpiece.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The cold rolling machine 10 shown in FIGS. 1 and 2 comprises a rotatably supported mandrel 12 and a pair of rotatable forming rolls 14. The mandrel 12 is supported at either end in bearings 16 held by a stationary holder 18, while the rolls 14 are rotatably mounted in bearings 20 in the arms 22 of yokes 24. These yokes are slidably mounted on a base 26 so as to be movable towards and away from one another. The holder 18 is fixed to the base 26.

As best shown in FIG. 4, the rolls 14 have annular humps 30 on either side of which are flat rolling portions 32. They, therefore, form a workpiece 34 into the shape of an inner bearing ring of a ball bearing. The edges of the rolls 14 have projecting flanks 60 whose function will be described in due course.

The mandrel 12 fits within the workpiece 34 and maintains a plain cylindrical inner facing surface on the workpiece during rolling. The relative sizes of the workpiece 34 and the mandrel 12 are such that the workpiece can freely slip onto the mandrel but, as soon as the rolls 14 squeeze the workpiece between themselves and the mandrel, the workpiece is squeezed against the mandrel which then rotates with the workpiece during the rolling operation.

The yokes 24 are slidably mounted on the base 26 so that they can both move towards and away from one another so as to effect the rolling of the workpiece 34. The yokes are caused to slide in this way by means of a pair of similar hydraulic rams 40. The two rams are hydraulically connected in parallel as will be described. In this way the two rolls 14 advance equally during rolling and do not put undue strain on the mandrel 12 and its bearings 16.

As noted above the rolls 14 must be advanced exactly together and this can be achieved to large extent by making the two rams 40 identical and then linking them hydraulically together in parallel so that hydraulic fluid supplied via the line 124 to advance the heads passes equally to each ram through branched lines 124a and 124b. Equally when the heads are to be withdrawn after a rolling operation, hydraulic fluid is supplied through the line 126 and this passes to each ram through branch lines 126a and 126b.

A suitable hydraulic circuit by which the rams 40 can be operated is shown as part of FIG. 2. Pressurized hydraulic fluid is supplied by a pump 150 to a supply line 152. Attached to this line are a pressure gauge 154 and a pressure safety valve 155. A branch line 156 leads from the line 152 to a control valve 158. This 158 controls the supply and return of fluid to the lines 124 and 126 which supply the rams 40 in parallel through the branch lines 124a and 124b and 126a and 126b so that both the rams move together. Included in the line 124 between the control valve 158 and the rams 40 is a flow control valve 164 to control the rate at which the rams can advance the rolls 14 during forming of the bank and having a return by-pass with a check valve 165 whose function will be described in due course, and a control valve 166 which is de-energised by a limit

switch 183 to change the piston advance speed from fast to slow.

With the valve 166 energised, the flow control valve 164 is by-passed and by operating control valve 158 the two rams 40 can be caused to advance at a fast approach speed. At a pre-set advance position the head contacts and trips the limit switch 183 which in turn de-energises the control valve 166 and causes the hydraulic fluid to pass through control valve 164 thereby causing the rams to advance slowly. The rolls 14 contact the blank at this slow speed and continue at this slow speed until full rolling depth is reached.

The retraction of rolls 14 is achieved by reversing the action of control valve 158. By this action, fluid is caused to flow through the line 126 and the branch lines 126a and 126b to the front of the rams 40, and fluid from behind the rams 40 to a reservoir 61 through the check valve 165 or through a control valve 166 which is energised at the same time as the control valve 158.

In order to ensure that equal and identical advancement of the two rolls 14 occurs, the two yokes can be mechanically linked together in a suitable way.

The advantage of this mechanical linkage is that the piston seals of the hydraulic rams can be cheaper and simpler and even slight leakage past these seals can be accommodated.

The two forming rolls 14 are rotated at the same rate by hydraulic motors being carried by the yokes 24. The advantage of driving the rolls 14 by hydraulic motors is that their reduction of rotation can be rapidly and simply reversed and this sometimes gives an improved finish to the rolled surface.

As shown in FIG. 3, annular collars 42 are provided which are mounted on the mandrel on either side of the workpiece and so rotate with the mandrel and workpiece. The collars 42 are urged against the sides of the workpiece by means of bellville springs 44 compressed between the collars and annular washers 46 which in turn bear on annular ridges 48 formed on the mandrel. These collars 42 do not prevent widthwise spreading of the workpiece but do ensure that the workpiece is accurately initially centred in relation to the annular humps 30 on the rolls 14 before rolling starts and the workpiece is contacted by the rolls 14. The force applied by the bellville springs 44 can alternatively be supplied by hydraulic or pneumatic rams operating directly on the annular collars 42.

In order to reduce substantially an ovality of the workpiece occurring during rolling, a pair of opposed growth control rolls 50 are provided. These are rotatably supported by bearings 55 which are carried in yokes 51 which are in turn attached to the piston rods 52 of hydraulic cylinders 53. The rolls 50 have annular humps 54 of the same or similar shape to the humps 30 on the rolls 14. If desired, however, the growth control rolls 50 can be plain cylinders.

The hydraulic cylinders 53 are connected in hydraulic parallel to a hydraulic power unit 151 via a change-over valve 58. During rolling pressured hydraulic fluid is supplied through lines 56 to the cylinders 53. This allows the pistons of the cylinders 53 to advance as the form is produced in the workpiece and prevents their retraction, thereby keeping the rolls 50 in contact with the workpiece 34 with sufficient force to prevent the workpiece from distorting to any large extent. This re-

duces metal fatigue and the subsequent possibility of fatigue of the workpiece during rolling.

They do not have any significant forming effect on the cross-sectional profile of the workpiece and instead merely follow the progress of forming by the rolls 14 and keep the workpiece in contact with the mandrel so reducing the oval-shaped distortion noted above. An additional flow control valve 200 is fitted in the return line 57 from cylinders 53 to ensure controlled approach of the growth control rolls to the workpiece.

On completion of rolling, the valve 58 is operated causing pressurised hydraulic fluid to be supplied to the cylinders 53 via lines 57 and a check valve 201. Outgoing hydraulic fluid from the cylinders returns to the reservoir 61 through the lines 56 and 59. This causes the growth control rolls 50 to be retracted from the workpiece.

To form an initially cylindrical workpiece this is first fitted on the mandrel 12. The arrangement is such that the inner hollow diameter of the workpiece is very slightly larger than the outer diameter of the mandrel. Therefore the workpiece can easily slide onto the mandrel.

Next the mandrel carrying the workpiece is reassembled in the machine and the forming rolls 14 are rotated. Additionally, the mandrel 12 and workpiece may be rotated by means (not shown) such as, an air or electric motor so that substantial slipping does not occur when the workpiece is contacted by the rolls 14. They are then forwarded towards one another by the hydraulic rams 40 and squeeze the workpiece and mandrel between themselves. The clearance between the inner hollow diameter of the workpiece and the mandrel is very small and as soon as the rolls 14 squeeze the workpiece they cause it to grip the mandrel and so both the workpiece and mandrel rotate together. Because there is no rolling between the mandrel and workpiece, the inner hollow surface of the workpiece is not formed or altered in shape.

The rate of rotation of the workpiece is governed by the roll speed, and the relative diameters of the components and rolls. In some cases a rate of rotation of the workpiece during rolling is 500 rpm.

During the rolling the annular humps 30 on the rolls 14 impress in the workpiece a corresponding annular groove.

Immediately after the forming rolls 14 have contacted the workpiece and made an initial impression and work hardening of the surface, the growth control rolls 50 are advanced to contact the workpiece and substantially reduce the extent of ovality which occurs. The rolls 50 shown in the drawings have annular humps which correspond to those on the rolls 14. The annular humps on the rolls 50 should, therefore, fit in the groove formed by the rolls 14. To assist this, it is preferred that the rolls 50 have some degree of freedom to move in the direction along their axes so that they can readily follow the forming operation without themselves shaping the workpiece.

The advancement of the rolls 14 continues at a rate of, for example, 0.010 to 0.020 inch per revolution of the workpiece until the rolls 14 reach their full advanced position. Once they reach the full rolling depth they, and the rolls 50, are maintained there for a time usually termed the "dwell time" for up to two revolutions of the workpiece and then all four rolls are withdrawn, all starting simultaneously. It is important to en-

sure that the workpiece makes the minimum number of revolutions at full rolling depth otherwise heating and fracture of the workpiece can occur. For example, the workpiece should not make more than about two revolutions after the rolls 14 reach full rolling depths.

After the rolling has been completed and the rolls 14 and 50 have retracted, the mandrel and workpiece are removed from the machine, and the workpiece removed from the mandrel. Then the operation can be repeated with a fresh cylindrical workpiece. The removal of the formed workpiece and introduction of a fresh workpiece is desirously effected automatically in any convenient way as will the other operations of the machine.

As will be appreciated the machine according to the invention described above is very effective in producing rolled parts and can do this with accuracy, consistency and speed. In addition, the provision of the rolls 50 ensures that metal fatigue and fracturing of the workpiece will not occur during forming.

In order to shape and form the side edges of the workpiece the rolls 14 have the projection flanks 60 which shape the side edges of the workpiece.

As seen in FIG. 4 the flanks 60 are not at right angles to the axis 61 of rotation of the roll. Instead they are inclined at an angle  $\alpha$  of up to  $15^\circ$  to the normal to the axis 63. This is found to prevent scuffing and slivering of the side edges of the workpiece which might break off and roll back into the rolled surface so damaging it. Additionally, this inclination is found to give better metal flow.

Also as shown in FIG. 4, as the metal flows during rolling to fill the profile of the rolls, the metal reaches the corners 70 and then flows up the side flanks 60. Because these flanks are only inclined at a small angle relative to the normal to the rotational axis 61 of the roll, any variation in the amount of metal flow, i.e., in the distance  $x$  will produce only an extremely small variation in the dimension  $y$ . Therefore provided the initial shape and size of the workpiece is accurately maintained, it is possible to produce rolled and shaped workpieces having a plane containing points Z which is always accurately spaced from the centre line W—W of the shaped workpiece, i.e., the profile given to the workpiece is always accurately located in relation to the plane containing the point Z. The workpiece should initially be centred before rolling and this is achieved by the collars 42 as described above. This, of course, is an important advantage when further operations, e.g., grinding, are to be effected on the rolled workpiece because then one has a conveniently and accurately positioned reference plane at the edge of the rolled workpiece.

Generally the initial workpiece has a small inside and outside diameter and narrower width than the finished shaped workpiece. The volume of the workpiece remains constant, however. The final dimensional tolerances of the shaped workpiece are largely dependent upon the size of the initial blank workpiece.

Also it is possible to form bore chambers 74 (FIG. 4) on the workpiece before or after rolling.

As best seen in FIG. 4 there are no sharp corners on the rolls 14, e.g., at the corners 70 and 72. All these corners have the maximum radius possible and the side flanks 60 lead from the corner radii with the portions 32 at a tangent. In this way, it is possible for the metal to flow easily in the direction of the arrows 101 so re-

ducing strains in the formed workpiece. This also is found to reduce any tendency of shaped workpieces to crack during a subsequent heat treatment.

The track roundness of a typical rolled inner bearing ring of about  $1\frac{1}{4}$  inches bore diameter prepared on the machine described above before and after heat treatment is shown in FIGS. 5 and 6, respectively, the graphs of FIGS. 5 and 6 being measured at the minimum diameter of the annular groove in the workpiece. Each radial division on the graph representing 0.0025 inch. As can be seen the out of round both before and after heat treatment is relatively small and little distortion occurs during first treatment showing that the ring has excellent grain flow structure and evenly disposed loop stresses. In addition, the small degree of out of round and the low distortion which occurs during heat treatment, reduces the amount of any final grinding required to finish the shaped workpiece to its final dimensions.

When forming inner bearing rings as described above in connection with the drawings, a material having a surface hardness of 25 to 32 Rc gives best results, although softer materials can be used.

FIGS. 7 and 8 show respectively the dimensions of a typical cylindrical workpiece before and after rolling according to the invention to the shape of an inner bearing ring. The workpiece was made of the material defined by the British Standards Institution as EN31 and it had a surface hardness of 27 Rc. The nominal diameter of the forming rolls 14 used as 10 inches and the "in feed" rate of these rolls during forming was 0.01 inch/revolution of the workpiece. The rate of revolution of the rolls 14 during forming was 62 r.p.m. The maximum rolling force applied by the rolls was 40,000 lb, and the dwell time was 0.75 second.

The various dimensions A to I on FIGS. 7 and 8 were in inches as follows:

- A—1.5644
- B—1.138
- C—0.584
- D—1.6082
- E—1.1712
- F—0.648
- G—0.6397
- H—0.6397
- I—1.4523

The cold rolling machine 80 shown in FIG. 9 is for providing a profile on the inner facing surface of a cylindrical workpiece 82 so forming, for example, an outer bearing ring. The workpiece is rolled between a profiled inner roll 84 which is rotatably carried by means (not shown) and an outer cylindrical roll 86 also rotatably carried by means (not shown).

The inner roll 84 has an annular hump 88 on either side of which are plain cylindrical portions 89 on either side of which are in turn flanks 90. It therefore has a profile similar to that of the rolls 14 described above, the equivalent parts of the roll 84 serving similar functions.

Therefore, provided the workpiece is initially centred in relation to the hump 88, workpieces are accurately formed with a side edge which can be used to locate the rolled workpiece accurately for further operations.

The workpiece is initially centred by means of a resiliently mounted collar 92 and cup-shaped hood 94. The collar 92 fits within the roll 86 and has an annular flange 96 which is fixed to the roll 86 by screws 98. Be-

tween the heads of the screws 98 and the flange 96 are spring washers 100. It is, therefore, possible to move the collar 92 in the direction of the arrow 102 so compressing the washers 100. The cup-shaped hood 94 also fits within the roll 84 and is mounted on a rotatable thrust bearing (not shown) mounted in its turn on the end of a rod 104 connected to a pneumatic cylinder.

The workpiece 82 is mounted in the roll 86 by first sliding it into place against the collar 92, the workpiece having a slightly smaller outer diameter than the internal diameter of the roll 86, then it is pressed towards the left as shown in FIG. 9 by the hood, a predetermined pressure being applied in the pneumatic cylinder to compress the spring washers 100 sufficiently to bring the workpiece to the accurately desired location. Because the washers 100 and pneumatic cylinders have some resiliency they do not inhibit width-wise spread during rolling.

The roll 84 is rotated, say, at 500 r.p.m., although, the exact rate depends as noted above upon the roll speed and the relative diameter of the various components, and the cylindrical roll 84 is also pre-rotated so that when the workpiece is contacted by the roll 84 there is substantially no slipping.

Next the rolls 84 and 86 are moved in the direction of the arrow 106 relative to one another to squeeze and form the workpiece. During rolling the workpiece expands slightly in diameter to fit within the roll 86. This ensures an accurately final outside diameter.

It will be noted that the inner bore of the roll 86 flares slightly towards the right as seen in FIG. 9. This makes it easier to insert and withdraw the workpiece.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

I claim:

1. A method of forming to shape an initially cylindrical workpiece comprising initially locating said cylindrical workpiece along its cylindrical axis relative to a pair of forming members at least one of which is a forming roll having a profile to be squeezed into said workpiece, and then rolling and squeezing said workpiece between said pair of forming members to impress in said workpiece by metal flow said profile, at least said forming roll having said profile to be squeezed into said workpiece having radially outwardly diverging flanges at its edges which during said rolling step controls the shape of the edges and the width-wise spreading of said workpiece, said flanges being angled at an angle of up to 15° to the normal to the axis of rotation of said roll.

2. A method according to claim 1 in which said workpiece is mounted between opposed spring means to locate it relative to said forming rolls before being formed to shape.

3. A method according to claim 1 in which a profile is rolled into the outer facing surface of said workpiece, said workpiece being rotatably supported on a mandrel and said profile being impressed into the outer facing surface of said workpiece by said profiled forming roll.

4. A method according to claim 3 in which said profile is squeezed into said outer facing surface of said

workpiece by a pair of diametrically opposed profiled forming rolls.

5. A method according to claim 1 in which a profile is rolled into the inner facing surface of said workpiece by squeezing said workpiece between an inner profiled forming roll positioned within the workpiece and an outer cylinder within which said workpiece is positioned.

6. A machine for rolling a workpiece to a desired shape comprising a rotatable mandrel over which said workpiece is to fit so as to be supported by said mandrel during rolling, at least two heads evenly angularly spaced around the periphery of the workpiece, each head being capable of carrying a driven forming roll shaped to roll the workpiece to the desired shape and being constrained so that said rolls are movable relative to the workpiece in a direction radially of said workpiece so that said workpiece is shaped by being squeezed by the forming rolls, location means for initially locating the workpiece along its axis relative to said forming rolls, and a number of rotatably supported growth control rolls which are spaced around said workpiece, are arranged to remain in contact with the workpiece during rolling in peripheral regions between said forming rolls, and are arranged to be prevented from retracting during rolling so avoiding substantial deformation of said workpiece from the circular and preventing undue metal fatigue.

7. A machine according to claim 6 in which said growth control rolls are arranged to be urged against said workpiece during rolling by means of hydraulic rams which maintain the growth control rolls in contact with said workpiece and which are arranged to prevent said growth control rolls from retracting during rolling.

8. A machine according to claim 6 in which said growth control rolls have a form which is the same as that on said forming rolls.

9. A machine according to claim 6 in which said growth control rolls have a form which is similar to that on said forming rolls.

10. A machine according to claim 6 in which said growth control rolls are resiliently movable in a direction along their rotational axes.

11. A machine according to claim 6 which has a pair of diametrically opposed heads arranged to carry said forming rolls and a pair of diametrically opposed growth control rolls spaced at 90° with respect to said forming rolls.

12. A process for rolling a workpiece to a desired shape using a machine according to claim 6 in which said workpiece is initially located along its axis by said location means, is then squeezed by said forming rolls sufficiently to indent the workpiece to start the shaping of said workpiece and form a location for said growth control rolls and thereafter said workpiece is contacted by said growth control rolls, said growth control rolls contacting said workpiece with a force sufficient to prevent substantial deformation from the circular between the forming rolls but insufficient to cause substantial forming of said workpiece and, after said workpiece has been rolled to the desired shape, and forming rolls and said growth control rolls all start retracting at the same time.

13. A process according to claim 12 in which said workpiece has an outside diameter of up to 4 inches.

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14. A process according to claim 12 in which said forming rolls advance at a rate of from 0.010 to 0.020 inch per revolution of the workpiece.

15. A machine for rolling a workpiece to a desired shape comprising:

a rotatable mandrel having an axis, said mandrel being capable of rotatably supporting said workpiece,

a pair of heads arranged diametrically opposite one another relative said axis of said mandrel, said heads being constrained to move in the radial direction relative said axis of said mandrel,

a forming roll rotatably supported by each head, said roll having a forming profile to be squeezed into said workpiece, and radially outwardly diverging flanges at its edges, said flanges diverging at an angle of up to 15° to the normal to the axis of rotation of said roll,

hydraulic ram means for progressively and substantially equally advancing said heads so as to squeeze and form said workpiece to shape, a pair of rotatably supported growth control rolls arranged diametrically opposite one another and at 90° to said forming rolls,

hydraulic ram means for urging said growth control rolls in contact with said workpiece during rolling and substantially preventing retraction of said

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growth control rolls during rolling, and opposed spring means on said mandrel between which said workpiece is arranged to be held prior to and during rolling so as initially to locate said cylindrical workpiece along its axis relative said forming rolls.

16. A method of forming to shape an initially cylindrical workpiece comprising initially locating said cylindrical workpiece along its cylindrical axis relative to a pair of forming members at least one of which is a forming roll having a profile to be squeezed into said workpiece, at least said forming roll having said profile to be squeezed into said workpiece including radially outwardly diverging flanges at its edges, said workpiece being positioned equidistant from said inclined flanges of said workpiece, holding said workpiece in said initial location, and rolling and squeezing said workpiece between said pair of forming members to impress in said workpiece by metal flow said profile, wherein said outwardly diverging flanges of said forming roll controls the shape of the edges and the width-wise spreading of said workpiece during said rolling step and wherein said workpiece follows the contour of the flanges but does not fill the nip between the opposed forming rolls, said flanges being angled at an angle of up to 15° to the normal to the axis of rotation of said roll.

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