Sept. 2, 1941. J. M. CHRISTMAN 2,254,674

METALWORKING

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FIG. 1.

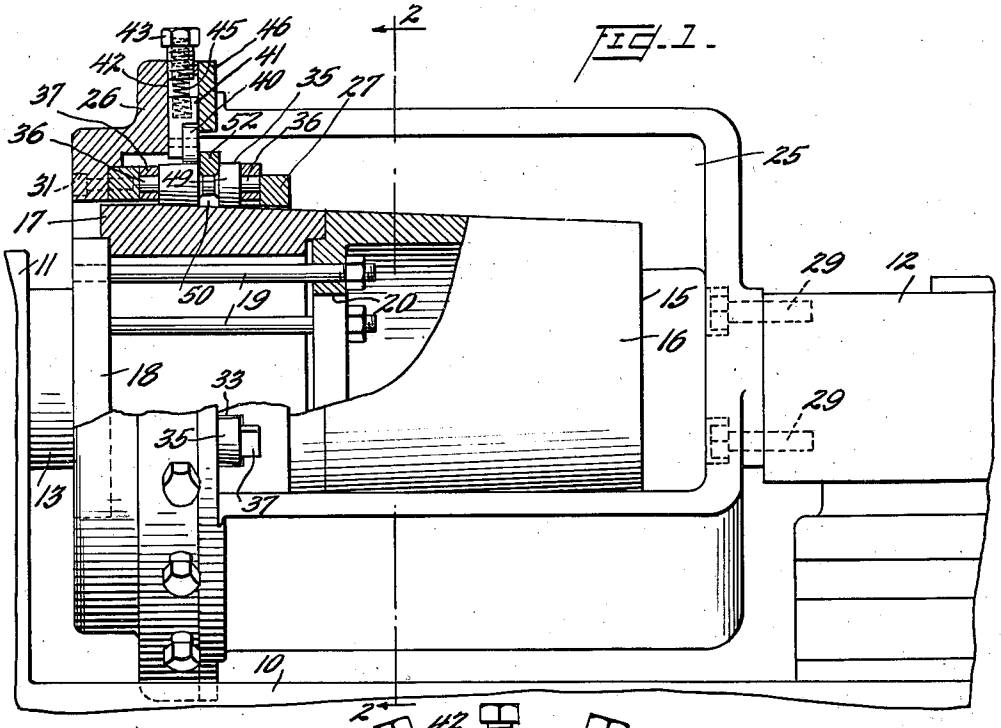
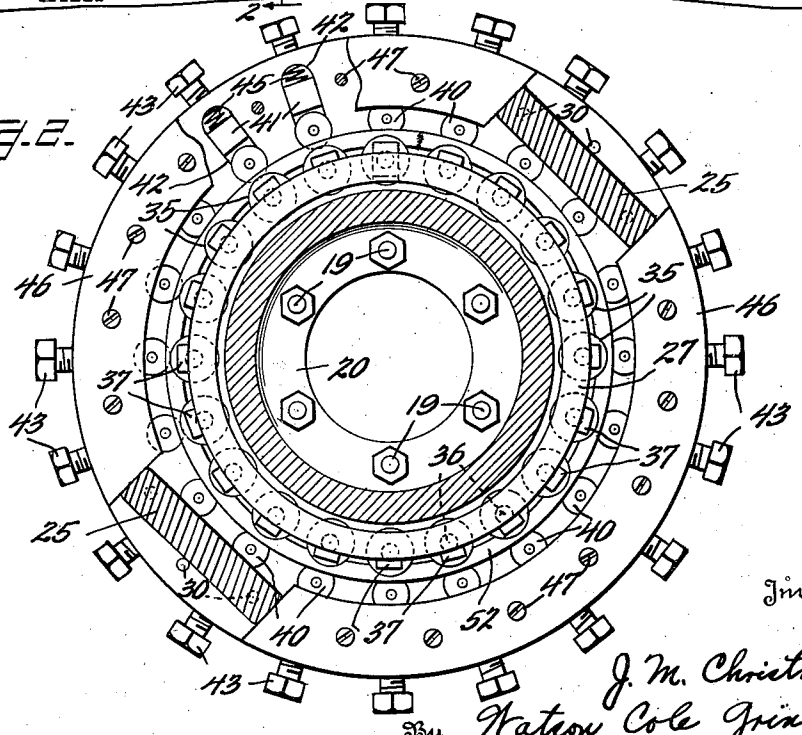


FIG. 2.



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METALWORKING

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FIG. 3.

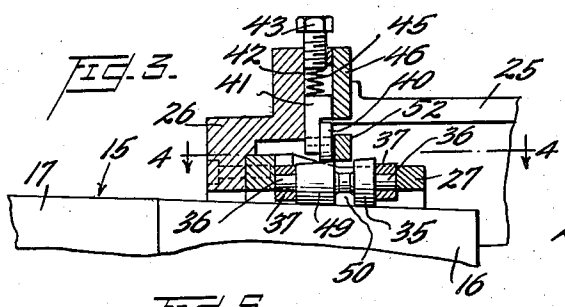


FIG. 4.

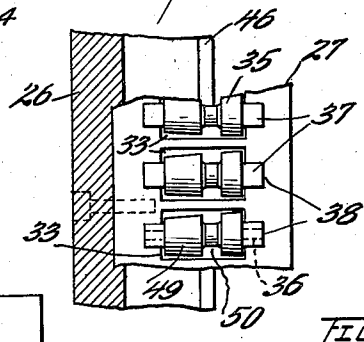


FIG. 5.

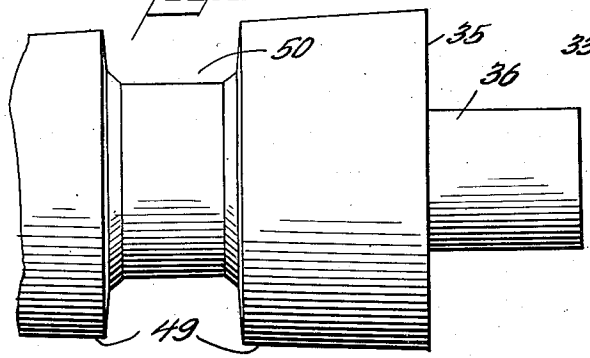


FIG. 6.

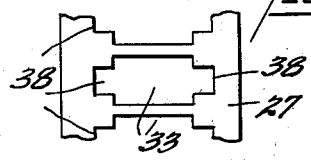


FIG. 7.

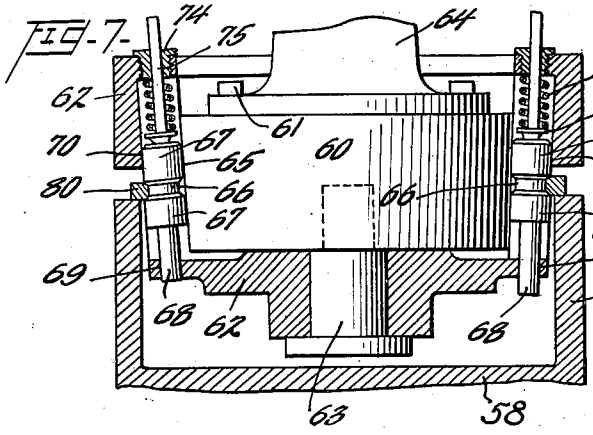


FIG. 8.

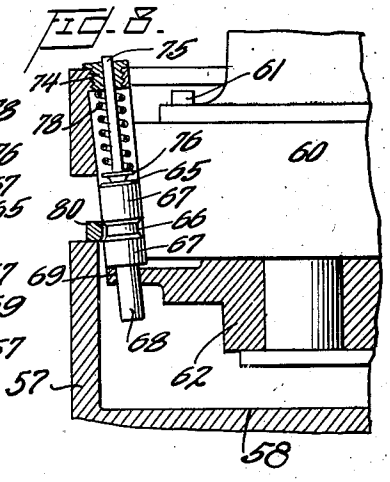


FIG. 9.

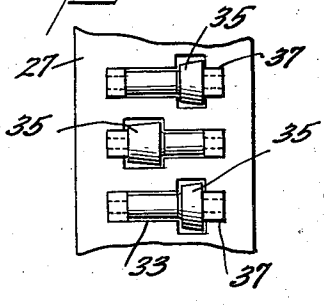
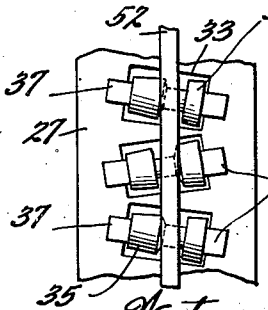


FIG. 10.



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FIG. 11.

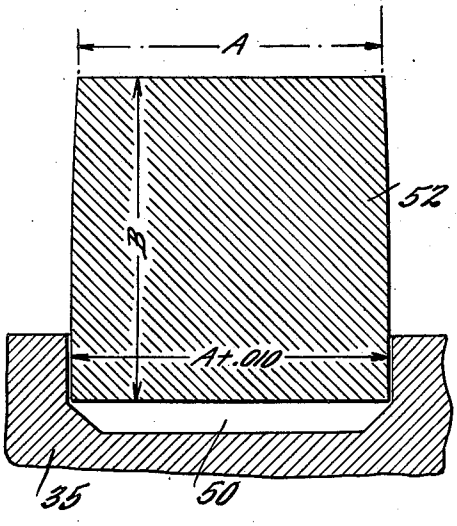


FIG. 12.

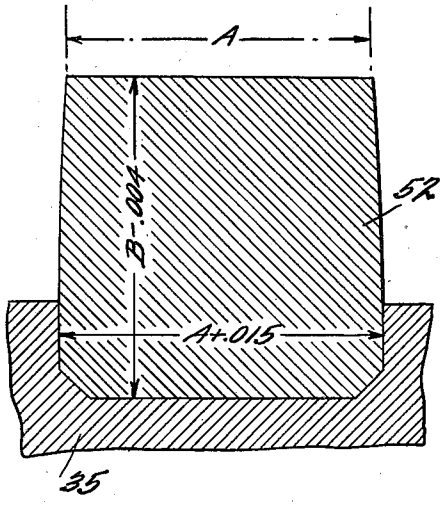
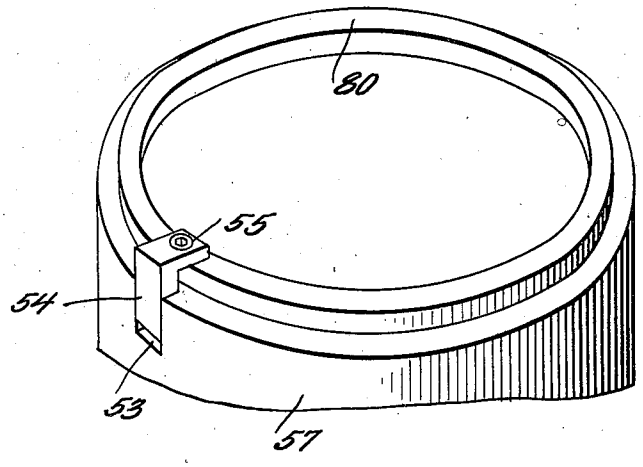


FIG. 13.



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Patented Sept. 2, 1941 2,254,674

UNITED STATES PATENT OFFICE

2,254,674

METALWORKING

John M. Christman, Detroit, Mich., assignor to Packard Motor Car Company, Detroit, Mich., a corporation of Michigan

Original application May 31, 1935, Serial No. 24,426. Divided and this application March 2, 1939, Serial No. 259,461

7 Claims. (Cl. 80—5)

This invention relates to the formation of annular metallic bodies and has for its object the provision of an improved method of hardening and toughening such bodies and bringing them to the desired shape and size and of an apparatus which is capable of carrying out the method. The instant invention is a division of my prior application Serial No. 24,426, filed May 31, 1935, now Patent No. 2,175,378, October 10, 1939.

It is a more specific object of the invention to provide a method and apparatus for forming annular bodies such as ring gears or the like which involves the burnishing of the body, not only for the purpose of hardening and finishing the surface thereof, but in order to shape the body approximately into final form by deformation thereof, for instance within the limits imposed by conventional manufacturing tolerances.

Thus in the formation of ring gears which are commonly secured to the flywheels of internal combustion engines and are used for starting the engine, it is customary to employ metal blanks or bars of generally rectangular cross-section which are bent into annular shape, the ends of the bars being united for instance by butt welding, to complete the annulus. The annuli thus formed are finished by cutting operations on the side surfaces and the inner generally cylindrical surface thereof, and a number of the annuli are stacked together in alignment so that teeth may be simultaneously cut thereon. The process of finishing these annuli by cutting is fairly expensive and it is proposed by the present invention to substitute a burnishing step, whereby the side surfaces may be brought into approximate parallelism to facilitate stacking and the inner surfaces trued or stretched so that they may be readily shrunk on the portion of the flywheel which is provided to receive them, the annuli being deformed by rolling to the desired width with the side faces parallel.

If an elongated metal bar is bent into generally circular shape, it will be found that the inner thickness becomes greater than the outer thickness, so that in cross-section the bar assumes a generally trapezoidal shape. In accordance with the present invention it is proposed to apply such pressure to the annular body during the burnishing operation as to cause the metal to flow from the inner portion toward the outer portion of the annulus so that approximately parallel side surfaces may be secured without loss of metal and so that the annulus may be simultaneously toughened by the working to which it is subjected. For this purpose it is possible to obtain satisfactory results by burnishing only the inner surfaces and the inner portions of the side surfaces of the annuli, approximately true rectangular shape resulting from this method.

The saving of metal effected by practicing the present invention is a very important item. Thus it is found that in the more conventional process the blanks from which the annuli are formed must be of larger dimensions and contain considerably more metal than blanks which will suffice when the present invention is employed, it being necessary to remove metal during the cutting operation, whereas the rolling and burnishing of the blank, as proposed herein, merely deforms the blank and displaces the metal of which the blank is formed. For instance the annulus which is to be subjected to the rolling and burnishing operation may be of smaller inside diameter than is the finished article, the annulus being actually stretched during the forming operation in the manner hereinafter more particularly pointed out.

It is a more specific object of the invention to provide a burnishing machine which is capable of treating annular bodies wherein the burnishing means consists of a plurality of rollers disposed in generally circumferential arrangement and so shaped as to engage the inner surface and at least a portion of one side surface of the annulus to be burnished, these rollers being supported for generally radial displacement, whereby the annulus may be readily positioned on the rollers and the necessary pressure between the rollers and the annulus may be applied. In the preferred form of the invention radial movement of the burnishing rollers is obtained by means of a generally conical but only slightly tapered member with which the rollers are in rolling engagement, whereby axial movement of the support for the rollers and the member serves to thrust the rollers outwardly to apply the necessary pressure. This construction may be employed in connection with various conventional machine tools, for instance a lathe, the support for the rollers being carried by the tail stock and the generally conical member being carried by the head stock and arranged for rotation thereby, whereby the rollers will be rotated and the necessary burnishing action obtained.

Further objects and features of the invention will be apparent from the following description taken in connection with the accompanying drawings, in which

Figure 1 is a side elevation, partly in section of

burnishing apparatus constructed in accordance with the present invention, illustrating the several parts in their operative relationship;

Figure 2 is a transverse section taken substantially on the line 2—2 of Figure 1;

Figure 3 is a fragmentary sectional view corresponding to a portion of Figure 1 and illustrating the position assumed by the working parts during removal or application of a body to be burnished;

Figure 4 is a fragmentary sectional view taken substantially on the line 4—4 of Figure 3;

Figure 5 is an enlarged view illustrating one form of burnishing roller;

Figure 6 is a plan view of a portion of a carrier for the burnishing rollers;

Figures 7 and 8 are vertical sectional views illustrating a further modification of the invention and showing the positions which the parts assume during burnishing and rolling to size, and during removal or replacement of a body to be burnished respectively;

Figure 9 and 10 illustrate modified constructions and arrangements of the burnishing rollers shown in Figures 1 to 5 inclusive;

Figures 11 and 12 illustrate approximately the contour in transverse section which may be assumed by a blank before and after the rolling and burnishing operation respectively, showing the manner in which the metal is caused to flow during the operation; and

Figure 13 is a further modification of the construction shown in Figures 7 and 8.

For convenience in describing the invention, specific language is employed and detailed reference is made to the several embodiments thereof illustrated in the drawings. It will nevertheless be appreciated that no limitation of the scope of the invention is thereby intended, and it will be obvious that various further modifications and alterations will occur to one skilled in the art to which the invention relates.

Referring first to the form of the invention shown in Figures 1 to 6 inclusive, it will be observed that the burnishing apparatus disclosed therein is adapted to be associated with a lathe of conventional design having a base 10, a head stock 11, and a tail stock 12, the head stock including a member 13 which is rotated by operative connection with any convenient source of power and the tail stock being displaceable axially of and toward and from the head stock. Obviously the details of this structure form no part of the present invention except as they are associated with the apparatus now described.

This apparatus may comprise a member 15 which is rotatable by the head stock and which is of generally circular transverse section but which tapers from one end to the other so that the largest diameter thereof is adjacent the head stock. For convenience the member 15 may be formed of separate elements including a guide portion 16 which performs no function during the actual burnishing operation, and an annular element 17 which is preferably formed of hardened metal and which is so associated with the guide portion 16 as to form a tapered structure having a continuous periphery. Bolts 19 passing through apertures in an inwardly directed flange 20 formed on the portion 16 of the member 15 and threaded in a flange 18 constituting a portion of the head stock 11 may be employed to draw the elements of the member 16 into intimate engagement and to secure the same rigidly to the rotating portion of the head stock.

The other essential element of the structure is the support for the burnishing rollers which preferably includes a supporting yoke 25, an annular element 26, and a roller retaining cage 27, this support being secured rigidly to the tail stock of the lathe. Thus the supporting yoke 25 may be secured by bolts 29 to the tail stock 12 and by bolts 30 to the annular element 26. The retaining cage 27 is in turn bolted as indicated at 31 to the annular element 26, the arrangement being such that the cage 27 may surround the member 15, a slight clearance being provided between the cage and that portion of the member which is of the greatest diameter.

The retaining cage 27 is of generally annular shape and as shown more particularly in Figure 6 is provided with a series of circumferentially arranged slots 33, each of which is adapted to receive a burnishing roller 35 which is suitably supported in the cage for displacement in a generally radial direction and for rotation on its own axis.

Thus each burnishing roller 35 may be provided with trunnions 36 at the opposite ends thereof which are received in bearing members 37, the latter being of substantially rectangular outline and being supported for generally radial sliding movement in the narrower portions 38 at each end of the slots 33. Each burnishing roller is preferably urged in an inward, generally radial direction by means associated with the annular element 26 and preferably comprising a plurality of rollers 40, each of which engages one of the burnishing rollers 35 and is carried in a slide element 41 of generally rectangular outline, the latter being movable within a correspondingly shaped guide passage 42 formed in the annular element 26. At the outer end of each guide passage is threaded a closure member 43 and a compression coil spring 45 is interposed between each closure member and the associated slide element 41, the degree of compression of the springs 45 being thus adjustable by threading the corresponding closure members 43 inwardly or outwardly. For convenience the guide passages 42 may be formed as recesses in the generally radial face of the annular element 26, the outer sides of the recesses being closed by means of plates 46 which are of parti-annular shape and which lie between the two arms of the supporting yoke 25 and which are bolted as at 47 to the annular element 26, the arms of the supporting yoke 25 serving to close the remainder of the guide passage 42.

Each burnishing roller 35 is suitably hardened and is preferably, although not necessarily, formed to provide the trunnions 36 at either end thereof as hereinbefore described and an intermediate bearing portion having a surface 49 which is slightly tapered in the reverse direction of the taper of the cylindrical member 15 so as to provide for rolling engagement with the latter. Each roller is also preferably grooved as indicated at 50 to receive the annular body to be burnished, and the shape of this groove preferably conforms to that illustrated in Figure 5 of the drawings. Thus the base of the groove constitutes a pressure applying surface formed as a surface of revolution of which the generatrix is a substantially straight line, the lateral walls of the groove being tapered in an inward radial direction, slightly exaggerated in the drawing, so that the width of the base of the groove is slightly less than that of the outer portion thereof. This tapering of the lateral walls of the groove is not essential, but is desirable in order

that the annular body may be more readily withdrawn from the grooves on completion of the operation. As will be hereinafter more fully pointed out, the contour of that portion of the burnishing rollers which engages and actually burnishes the annular body may be varied to a considerable extent.

In this form of the invention the axes of the burnishing rollers are shown as parallel to each other and to the axis of the member **15** with which they cooperate. This construction is desirable in order that the lateral walls of the grooves in the rollers may be substantially straight-sided and not undercut on either side, the annular body moving directly radially inward as it is received within the grooves.

The mode of operation of the construction thus far described will be apparent. To initiate the burnishing operation the tail stock is displaced to the right as viewed in Figure 1 and toward that portion of the member **15** which is of smaller diameter, the burnishing rollers being thereby permitted to move inwardly under the action of the coil springs **45** so as to permit an annular body **52** to be burnished to be placed in position surrounding the rollers **35** immediately over the grooves **50** as represented in Figure 3. The tail stock is then displaced to the left and as the burnishing rollers slide on the member **15** they are forced outwardly into intimate engagement with the annular body **52** which is to be seated firmly in the grooves **50** of the rollers, the dimensions of the parts being such that as the tail stock approaches the extreme left-hand position as in Figure 1, considerable pressure is applied between the burnishing rollers and the annular body **52**, tending to seat the annular body in the grooves **50** of the rollers. The head stock and the cylindrical member **15** are now rotated to impart corresponding rotation to the burnishing rollers **35**, the annular body being thus rotated on the rollers in a direction reverse to the direction of rotation of the member **15**. As the burnishing operation progresses, the tail stock may be displaced further to the left, the annular body eventually seating fully within the grooves **50** of the burnishing rollers **35** and engaging the base of the grooves so that the inner surface of the annular body may be properly burnished.

In the event the annular body is formed in the manner hereinbefore described by deformation of an elongated bar of stock of generally rectangular cross-section and the butt welding of the ends of the stock to form a complete annulus, it is preferable to finish the welded portion to some extent to secure an approximation of uniform size before the burnishing operation is initiated. As already explained, this method results in the formation of an annular body of substantially trapezoidal cross-section, the inner portion being of greater width, and during the burnishing operation metal is caused to flow outwardly so that the body approaches a generally rectangular cross-section. It is preferred that only the inner portions of the side surfaces of the annular body be actually contacted with the lateral walls of the grooves **50** of the burnishing rollers, the depth of the grooves **50** being such that only the inner portion of the annular body will seat within the grooves at the completion of the operation. It is found that this method results in approximate parallelism of the side surfaces of the burnished annular body, the area burnished being of sufficient depth as measured radially to ensure the provision of adequate lateral seating surfaces. Thus if a ring gear for a flywheel starter is being burnished, the gears may be readily stacked with their burnished lateral surfaces in close engagement for the cutting of the teeth and these burnished surfaces will also afford a sufficiently true area for engagement with the corresponding surface on the flywheel. The inner surface of the ring gear is burnished by seating in the base of the groove to provide a true cylindrical contour for engagement with the corresponding cylindrical seat on the flywheel. As illustrated in the drawings, the base of each groove may be so formed as to provide chamfered inner edges on the annular bodies.

The manner in which the metal is deformed during the operation is indicated more particularly in Figures 11 and 12 of the drawings. Figure 11 shows the transverse section of an annulus which is about to enter the groove **50** in a roller **35**, the annulus having been first formed by the bending of a bar of stock and the welding of the ends. The inside diameter of the annulus at this stage is preferably less than that of the finished body and the width of the annulus, indicated in Figure 11 as $A+.010$, is preferably less than the width of the finished body. As the rollers are displaced outwardly, the annulus seats gradually in the groove **50** until it assumes the position in which it is shown in Figure 12, it being observed that the chamfered base of the groove **50** effects outward displacement of the metal of the annulus so that the latter is spread to increase the width thereof to completely fill the groove and engage the substantially straight lateral walls of the groove. At the same time the pressure applied to the annulus by the outward displacement of the rollers serves to stretch the annulus to increase the inside diameter thereof, and in practice it is advisable to increase this inside diameter to a somewhat greater value than that which will be required in the finished article to allow for slight springing and contraction due to the resilience of the article when the latter is removed from the machine. As shown in Figure 12, the depth of the annulus as measured radially has been slightly decreased by the process, the width at the base has been slightly increased, and the lateral walls are more nearly parallel, falling within conventional manufacturing tolerances. The inner portion of the lateral walls and the inner surface of the annulus are burnished by engagement with the corresponding walls of the rollers so as to work the metal and provide a hard and smooth finished surface.

It will be appreciated that Figures 11 and 12 are only illustrative of the general nature of the process. Thus it is by no means essential that the blank shall be so bent as to form an annulus of the general shape indicated in Figure 11 prior to the process; other shapes of blank may result from the bending operation, although in general the width of the outer portion of the blank will be less than that of the inner portion as the result of the bending of the straight blank into annular form. Similarly the shape of the grooves **50** as viewed in section need not conform to that shown in Figure 12; the chamfer may under some conditions be omitted and reliance may be placed on the radial stretching of the blank to force the metal outwardly against the lateral walls of the groove. The lateral walls of the groove may be straight or may be tapered to any extent necessary to facilitate withdrawal of the finished blank from the grooves.

It will also be immediately appreciated by one skilled in the art that various structural alterations of the machine may be made. Thus while it is convenient to rotate the member 15 and thereby the burnishing rollers, it is also feasible to rotate the annular body to drive the rollers, the member 15 or the equivalent thereof being retained against rotation. Again, while the rollers preferably contact directly with the outer surface of the member 15 they may alternatively be operatively connected with the member in some other manner, it being sufficient that the rollers are rotated on their own axes.

The burnishing rollers 35 need not be formed with grooves 50 in a cylindrical surface 49, but one end of each roller may simply be reduced in diameter as indicated in Figure 9 to afford a portion engaging with the inner surface of the annular body and a generally radial shoulder engaging with one side surface of the annular body, the shoulders on adjacent rollers facing in opposite directions so that each roller burnishes the inner surface only of one side or a portion of one side of the annular body. Such a construction facilitates the freeing of the annular body from the rollers as the tail stock is moved to the right on completion of the burnishing operation, it having been found that there is otherwise some tendency of the annular body to wedge tightly in the grooves 50 of the rollers and thus resist the effort of the springs 45 to force the burnishing rollers inwardly as the tail stock is displaced toward the smaller diametered portion of the member 15.

A further modified arrangement for facilitating withdrawal of the annular body from the rollers is shown in Figure 10 in which the axes of adjacent rollers are slightly inclined in opposite directions. While the rollers shown in this form of the invention are quite similar in contour to the rollers illustrated in Figures 1 to 5, principally for the purpose of affording adequate rolling contact between the rollers and the member 15, it is obvious that either one or both lateral walls of the groove in each roller may be arranged to engage with the adjacent side surface of the annular body, and in the event only one lateral wall of the groove actually effects burnishing of the body, the roller might be constructed as hereinbefore described to afford simply a shoulder formed by a reduced portion at one end of the roller.

For convenience in defining the disposition of the axes of the rollers, the latter are described as extending generally axially, it being understood that this definition is intended to include rollers of which the axes are inclined to some extent from a true axial direction, either in planes containing the axis of rotation of the member 15 or in planes transverse thereto as indicated in Figure 10.

It is of course possible to operate the several elements of the burnishing apparatus by means other than the conventional lathe structure, and various other metal working machines may be utilized for this purpose. Thus in Figures 7 and 8 the invention is illustrated as applied to a drill press, the burnishing rollers being supported for rotation on generally vertical axes. For instance, a slightly tapered member 60 having a smaller diameter at the lower end thereof may be secured as indicated at 61 to the spindle 64 of a drill press for rotation therewith, a support 62 for the burnishing rollers being secured for axial movement with the member 60 and for rotation with respect thereto, for instance by the bolt 63.

The burnishing rollers 65 which may be formed to provide a grooved portion 66 and cylindrical portions 67 having rolling contact with the member 60, are mounted in the support for sliding movement in a generally axial direction parallel to the outer surface of the cylindrical member 60. Thus each roller may be provided with a trunnion 68 received within a circular aperture 69 formed in the support 62 and further guided by engagement of a portion of the cylindrical surface thereof with a corresponding parti-cylindrical recess 70 formed in the upper end of the support. Threaded in the outer end of the recess 70 is a plug or closure member 74 within which is supported for sliding movement a plunger 75 having a head 76 engaging with the upper end of the associated burnishing roller. A coil spring 78 surrounds each plunger and urges the latter and the associated burnishing roller in a downward direction and toward the smaller diametered portion of the member 60. Thus when the drill spindle is raised, the burnishing rollers will be urged in a downward direction by the associated coil springs 78 and will assume the position indicated in Figure 8. In assuming this position each roller will of course move radially inward to some extent as the result of the inclination of the roller axis with respect to the axis of the member 60, and it is thus possible to position an annular body 80 about the burnishing rollers and in abutting relation with the upper lateral wall of the groove of each roller. As the drill spindle is now moved downwardly toward the stationary work holder 58, the lower side surface of the annular body engages with the stationary annular flange 57, thereby preventing further downward movement of the burnishing rollers 65 with the member 60. As downward movement of the member 60 and the support 62 continues, each burnishing roller is displaced outwardly as the result of the relative upward movement of the rollers in the support. In other words, the rollers are engaged by portions of the member 60 of constantly increasing diameter, and pressure is thus applied between the rollers and the annular body to force the latter into the grooves in the rollers as shown in Figure 9. On rotation of the member 60 the rollers will be rotated and the annular body thus burnished, the member 60 being moved further downwardly, if necessary, during the burnishing operation in order to seat the body more fully in the grooves 66. The whole operation is thus quite similar to that of the embodiment of the invention first described, with the exception that the annular body 80 rather than the support for the rollers is retained against rotation, the annular body being held as the result of frictional engagement thereof with the upper surface of the stationary flange 57, the downward thrust of the springs 78 being sufficient for this purpose. The roller support 62 and the roller 67 will of course execute planetary movement about the axis of the member 60, the latter functioning as a driving sun and the annular body 80 acting as a fixed orbit.

Under some circumstances it is found desirable in this form of the invention to positively retain the annular body 80 against rotation. For instance as shown in Figure 13, the upstanding annular flange 57 may be provided with one or more axially extending slots 53 which are arranged to receive a generally L-shaped ele-

ment 54 of which one leg extends into the slot and the other leg is secured as at 55 to the annular body 80. Such an arrangement prevents rotation of the annular body while at the same time permitting the radial expansion or stretching thereof which ordinarily results from the processing and sizing operation.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In apparatus for burnishing annular bodies, the combination with a support, of a plurality of rollers carried by said support in circumferentially spaced relation, each roller being provided with a generally cylindrical burnishing surface for engagement with the inner surface of the body, and with one generally radial surface for burnishing engagement with a side surface of the body, alternate rollers being arranged to engage and burnish opposite side surfaces only of the body.

2. In apparatus for burnishing annular bodies, the combination with a support, of a plurality of rollers carried by said support in circumferentially spaced relation, each roller being provided with a generally cylindrical burnishing surface for engagement with the inner surface of the body, and with at least one generally radial surface for burnishing engagement with the inner portion only of a side surface of the body, whereby bodies having a greater thickness at the inner portion than the outer portion thereof may be deformed to approach uniform thickness, means for applying pressure between the coacting surfaces of said roller and body, and means for rotating said rollers on the axes thereof.

3. In apparatus for burnishing annular bodies for use with a lathe having a rotating head stock and an axially displaceable tail stock, the combination with a support adapted to be secured to the tail stock, of an axially tapered member adapted to be secured to the head stock, and a plurality of burnishing rollers carried by said support for generally radial displacement with the axes thereof directed generally axially of the lathe and with surfaces thereon for rolling engagement with said member, said rollers having burnishing surfaces for engagement with a body to be burnished, whereby said rollers may be rotated on rotation of said member and head stock and may be displaced inwardly or outwardly to release the body or to engage and apply pressure thereto on axial displacement of said support and tail stock.

4. In apparatus for forming annular bodies, the combination with means for applying outwardly directed and uniformly distributed rolling pressure to the inner surface of an annular blank concurrently at a plurality of points spaced circumferentially of the blank, means for effecting outward and circumferential displacement of said first named means with respect to said blank during such application of pressure, whereby the diameter of such inner surface is increased and metal is caused to flow outwardly of such inner surface, and means for simultaneously so confining further portions of the surface of the blank as to permit slight lateral expansion of said last named portions but prevent such lateral expansion beyond predetermined planes substantially normal to the blank axis.

5. In apparatus for forming annular bodies, the combination with means for applying outwardly directed rolling pressure to the inner surface of an annular blank concurrently at a plurality of points spaced circumferentially of the blank, said means comprising a plurality of rollers, each roller having the pressure applying surface thereof formed as a surface of revolution of which the generatrix is a substantially straight line, means for effecting outward and circumferential displacement of said first named means with respect to said blank during such application of pressure, whereby the diameter of such inner surface is increased and metal is caused to flow outwardly of such inner surface, and means for simultaneously so confining the side surfaces of the blank as to permit limited lateral expansion only of such surfaces and to restrict the lateral thickness of the expanded blank to a predetermined maximum.

6. In apparatus for forming annular bodies, the combination with means for applying outwardly directed rolling pressure to the inner surface of an annular blank concurrently at a plurality of points spaced circumferentially of the blank, said means comprising a plurality of rollers, each roller having the pressure applying surface thereof formed as a surface of revolution of which the generatrix is a substantially straight line, means for effecting outward and circumferential displacement of said first named means with respect to said blank during such application of pressure, whereby the diameter of such inner surface is increased and metal is caused to flow outwardly of such inner surface, and means for simultaneously so confining the lateral surfaces of the blank as to prevent expansion thereof beyond planes substantially normal to the blank axis and having a predetermined spacing.

7. In apparatus for shaping continuous annular metal bodies of nearly rectangular section, having a thickness slightly greater at the inner than at the outer surface, the combination with means for engaging and rolling the inner surface at a plurality of circumferential spaced points with sufficient, uniformly distributed pressure to cause permanent stretching of the annulus, and means for simultaneously confining the inner portions of the side surfaces of the annulus adjacent the said spaced points so as to permit slight expansion thereof but to prevent such expansion beyond substantially parallel planes.

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