July 22, 1969 R. J. WELSH 3,456,394

GRINDING MACHINES

Filed Nov. 26, 1965 2 Sheets-Sheet 1

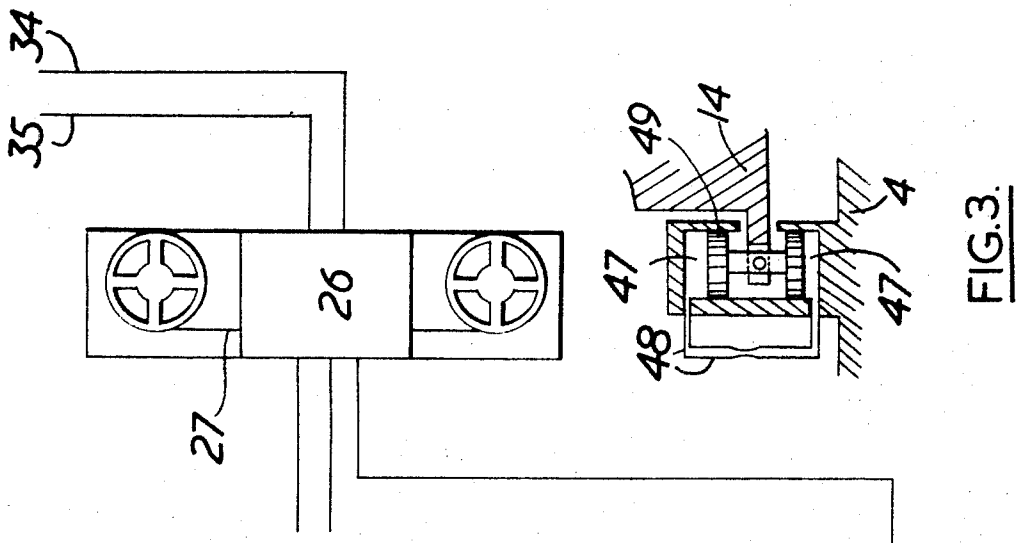


FIG.3.

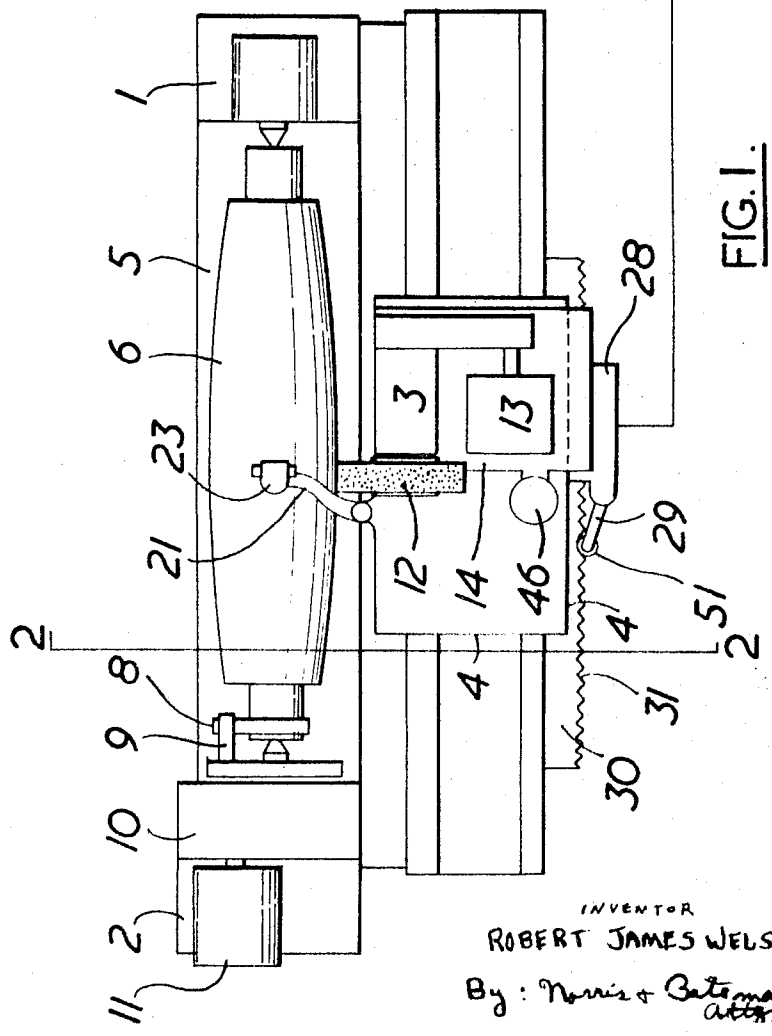
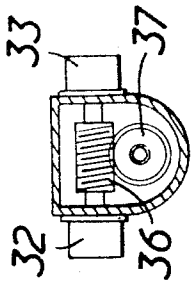


FIG. 1.

FIG.4.



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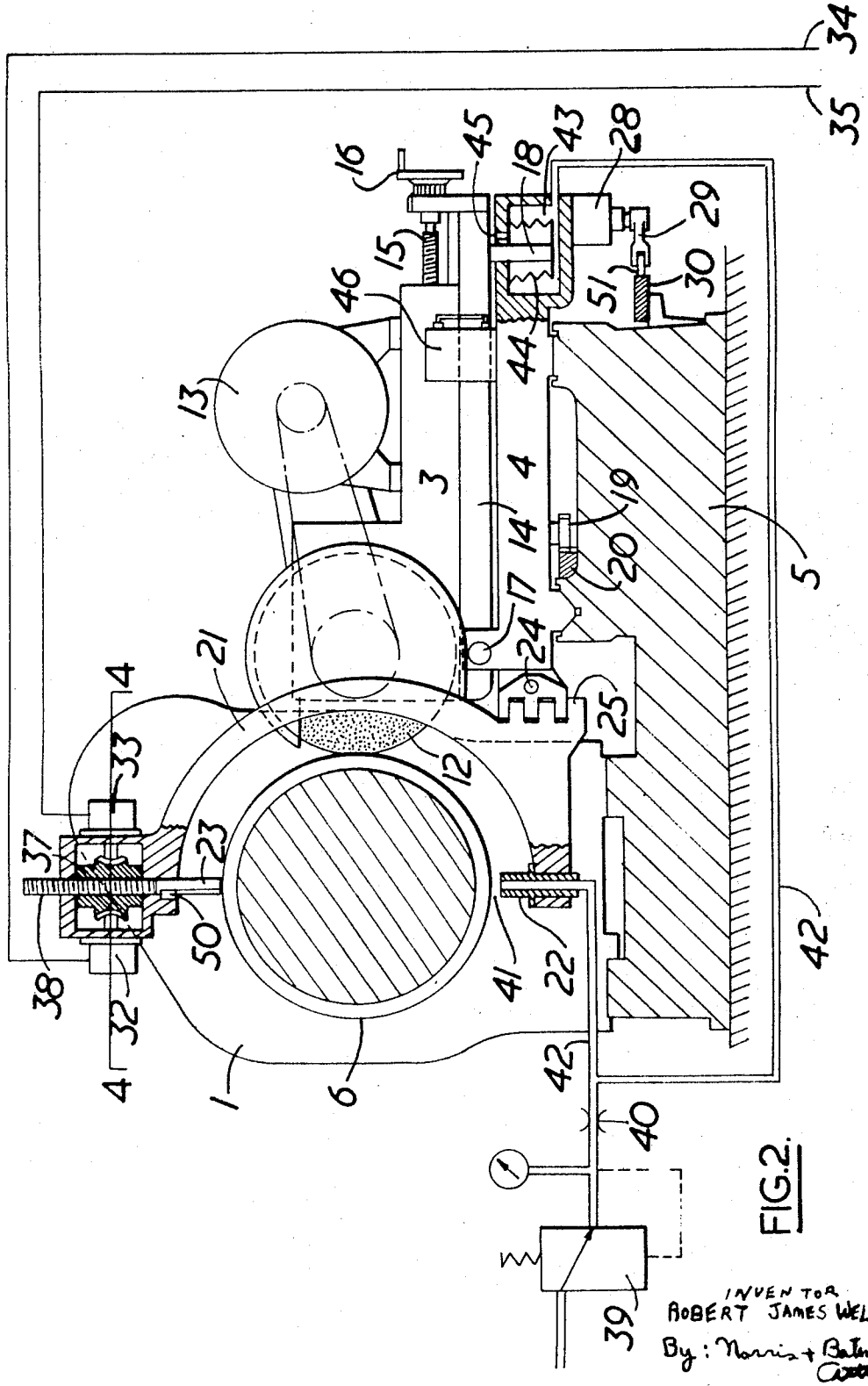


FIG.2.

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GRINDING MACHINES

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U.S. Cl. 51—165 14 Claims

ABSTRACT OF THE DISCLOSURE

A grinding machine on which a workpiece can be supported and rotated to be operated on by a grinding wheel which can be moved axially and radially, a pneumatic sensing device is provided to sense any variation in diameter of the workpiece from a datum diameter and a signal from the sensing device actuates a mechanism which applies a force to control the radial position of the grinding wheel in accordance with variation from the datum diameter.

This invention relates to machines for grinding the curved surface of round bars, and in particular although not exclusively to the grinding of rolls such as are used in steel making, paper making and other industries. Since such rolls tend to deflect in service it is common practice to counter this by constructing them in a barrel form, that is to say with a slightly longer diameter at the centre of the roll than at the ends.

It is known for the change in diameter from one end of the roll to the other to follow one of several types of curve such as a parabolic curve, a sinusoidal curve, a circular arc or an arbitrary curve, and the usual method of producing such forms comprises mounting the roll in a substantially rigid housing, rotating it, and grinding it by contact with the periphery of a cylindrical grinding wheel rotating on an axis which is substantially parallel to the axis of the roll. The grinding wheel is moved axially along the roll, and at the same time it is moved radially relative to the roll to produce the required form.

Usually the radial movements are produced by mechanical means consisting of a plurality of levers often associated with a form of cam suitably arranged to move the grinding wheel radially for a certain distance depending on its axial position. It is also known to provide an automatic gauging device adjacent to the grinding wheel which is adapted to sense any changes in the diameter of the roll and compare the sensed diameter with the required diameter, the value of which is fed by appropriate means for a master template, which may be in the form of a cam. The gauging device produces an error signal corresponding to any difference between these two diameters and compares it with a similar signal from a further device adapted to measure the power of the motor driving the grinding wheel. Any difference between these two signals motivates means for effecting a movement of the grinding wheel towards or away from the roll thus increasing or decreasing the power absorbed by the grinding wheel, and thus tending to maintain the power output of the grinding wheel motor at a value roughly proportional to the value of the error signal from the gauging device.

Automatic gauging in conjunction with automatic sizing on cylindrical grinding machines is well known and is carried out in various ways. All the methods, however, have in common the same characteristic of providing a relatively high rate of grinding when the gauge indicates that the diameter of the portion of the roll being ground is substantially larger than the required diameter, and providing a relatively low rate of grinding when the gauge indicates

that the workpiece is approaching the desired diameter.

It is an object of the present invention to provide a grinding machine having a much simpler form of construction than hitherto. A further object of the invention is to provide a construction in which the signal from the gauging device may effect variations in the rate of metal removal more directly than hitherto thereby avoiding the cost and the complexity as well as the inherent unreliability of some of the intermediate devices commonly used in other constructions. A further object of the invention is to provide a simplified construction whereby changes from one form of camber to another may be effected simply by a relatively inexpensive input member of a numerical control device.

According to the present invention a grinding machine comprising means for supporting and rotating a workpiece, a grinding wheel adapted to be moved axially and radially relative to the workpiece and means for applying a predetermined force to the grinding wheel in a substantially radial direction relative to the workpiece is characterised in that gauging means are provided having a signal output which is related to the difference between the actual diameter of the workpiece and a datum diameter, the signal output being adapted to determine the force which is applied to the grinding wheel, such that at any one axial position of the grinding wheel relative to the workpiece the signal output produces a discrete and predetermined force irrespective of the type of grinding wheel employed, irrespective of the workpiece material and irrespective of the speed of grinding, whereby a higher force is applied to the grinding wheel when the portion of the workpiece being acted upon by the grinding wheel is substantially larger than the datum diameter, and a lower force is applied when the gauging means indicates that the workpiece is approaching the datum diameter.

Preferably means for varying the datum diameter are provided which may conveniently be a numeric control tape reading device provided with a suitable programmed tape which is fed through the tape reading device at a speed proportional to the rate of axial movement of the grinding wheel.

The gauging means may be of a known type, but it is preferred to use a pneumatic type with a signal output in the form of a manometric air presure varying inversely with a function of the gap between the gauge and the workpiece.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which

FIG. 1 is a plan view of a grinding machine constructed in accordance with the invention,

FIG. 2 is a cross-sectional view of the machine along line 2—2 in FIG. 1,

FIG. 3 is a cross-sectional view illustrating the operation of a hydraulic damper incorporated in the machine, and

FIG. 4 is a cross-sectional view of the machine along line 4—4 in FIG. 2.

The grinding machine comprises a tailstock **1**, a workhead **2**, a wheelhead **3** and a carriage **4** mounted on a substantial base **5**, FIG. 1.

A workpiece **6** is located between the tailstock **1** and the workhead **2** and rotated at a suitable speed by driving a plate **8** through a driving pin **9** from a reduction unit **10** and a motor **11**.

The wheelhead **3** carries a grinding wheel **12** driven by a further motor **13**, and is capable of being traversed in a direction normal to the workpiece axis on its base **14** by a screw **15** through a graduated handwheel **16**. FIG. 2.

The sub-base **14** is supported at its end adjacent to the

workpiece 6 by trunnions 17 and at its opposite end by a rod 18.

The carriage 4 is capable of being traversed along the base 5, parallel to the axis of the workpiece 6, by a pinion 19 driven by a motor (not shown) mounted on the carriage 4 engaging with a rack 20 which is attached to the base 5.

A caliper frame 21 carries a gauge head 22 and an adjustable probe 23. The probe 23 is maintained in continuous light contact with the upper part of the workpiece 6. The frame 21 is attached to the carriage 4 by a trunnion 24 and hinge 25.

The distance between the gauge head 22 and the probe 23 is controlled from a numerical tape reading device 26, in the following manner.

A tape 27 is fed through the reading device 26 by a signal from switch 28. The rate of feed is proportional to the rate at which the switch level 29 is oscillated as it is traversed by the carriage 4 along a plate 30. Notches, teeth or grooves 31 in the plate 30 are followed by a roller 51 which imparts an oscillating movement to the switch lever 29. Each cycle of oscillation of the lever 29 causes the tape 27 to advance by one character.

By this means the position of the tape 27 in the reading device 26 is always directly related to the position of the carriage 4 on the base 5, and thus to the axial position of the caliper 21 on the workpiece 6.

Each notch 31 in plate 30 thus represents a discrete station in the axial traverse of carriage 4 and is represented by a corresponding discrete character on the tape 27.

Characters on the tape 27 may be "nil" characters and produce no signal, or they may be action characters giving a signal either along line 34 or line 35.

A signal on line 34 will operate a stepping mechanism 32 which acts through a worm 36 and a worm wheel 37 to cause a reduction in the distance between the probe 23 and the gauge head 22 by the wormwheel 37 acting as a nut on a screwed portion 38 of the probe 23 which is restrained against rotation by a key 50. Conversely a signal on line 35 will operate a further stepping mechanism 33 and cause an increase in the distance between the probe 23 and the gauge head 22.

Successive characters on tape 27 are programmed in such a sequence as to vary the distance between probe 23 and gauge head 22, in sympathy with the required diameter of the workpiece 6 at the point of contact between the grinding wheel 12 and the workpiece 6, corresponding to each of the aforesaid discrete stations of axial position.

An alteration in the distance between the probe 23 and the gauge head 22 will result in a similar change in the gap 41 between the gauge head 22 and the workpiece 6.

Air is supplied through a regulator 39 and a flow control device 40 through the lines 42 to the gauge head 22 and a cylinder 43.

Reduction of the gap 41 restricts the flow of air through the gauge head 22 resulting in an increase in pressure in the line 42 and in the cylinder 43.

The pressure in the cylinder 43 acts on a corrugated cylindrical bellows 44, closed and connected to rod 18 at one end and with its internal volume vented through hole 45 to the atmosphere.

The increase in pressure caused by any reduction in the gap 41 will tend to collapse the bellows 44 and increase the vertical thrust in the rod 18.

This tends to rotate the sub-base 14 and wheelhead 3 about the trunnions 17 resulting in an increased pressure between the grinding wheel 12 and the workpiece 6.

At some value of gap 41 the pressure in line 42 and cylinder 43 will be such that the force exerted by the rod 18, by the tendency of the pressure to collapse the bellows 44, will be sufficient to maintain equilibrium of the sub-base 14 about the trunnions 17.

Therefore, a reduction in the gap 41 giving rise to increased pressure in the cylinder 43 will give a rise in pressure between the grinding wheel 12 and the workpiece 6 and by the action of grinding this will reduce the diameter of the workpiece 6 until the state of equilibrium between the gap 41 and the sub-base 14 is restored.

Thus the force set up by the air pressure becomes a force tending to move the grinding wheel 12 radially relatively to the workpiece 6. Such force will vary inversely with the gap 41, and through the action of grinding tend to produce a workpiece 6 of a shape which is in sympathy with the programmed tape 27 by maintaining a substantially uniform gap 41 at all positions in the axial length of the workpiece.

To prevent any tendency for the grinding wheel 12 to produce a non-circular workpiece 6, by reason of too rapid radial movements of the sub-base 14 about the trunnions 17, a damping device 46 restrains the movement of the sub-base 14 relative to the carriage 4. In this example, FIG. 3. The damping device 46 consists of two strongly constructed closed spaces 47 attached to the carriage 4, connected by a capillary tube 48 and filled with a suitable liquid so that any relative radial movement of the sub-base 14 will move the double piston 49 and cause the transfer of liquid from one closed space 47 to the other through the capillary tube 48.

I claim:

1. A grinding machine comprising means for supporting and rotating a workpiece, a grinding wheel mounted to be moved axially and radially relative to the workpiece, means for rotating said grinding wheel, means for substantially continuously applying a predetermined force urging the grinding wheel in a substantially radial direction relative to and against the workpiece, gauging means operatively associated with said workpiece to continually provide a signal output which is related to the difference between the actual diameter of the workpiece at the point of contact between the workpiece and grinding wheel and a datum diameter, and means actuated by said signal output and operatively connected to said force applying means for determining and automatically variably controlling said force applied to the grinding wheel in accordance with said diameter difference.

2. A grinding machine comprising means for supporting and rotating a workpiece, a grinding wheel mounted to be moved axially and radially relative to the workpiece, means for driving said grinding wheel, means for applying a predetermined force to the grinding wheel in a substantially radial direction relative to the workpiece, gauging means operatively associated with said workpiece to provide a signal output which is related to the difference between the actual diameter of the workpiece at the point of contact between the workpiece and grinding wheel and a datum diameter, means for varying the datum diameter comprising a control tape reading device and a programmed tape for use with the tape reading device and means for feeding said tape through the tape reading device at a speed proportional to the rate of axial movement of said grinding wheel, and means actuated by said signal output for determining and applying said force to the grinding wheel in accordance with said diameter difference.

3. A grinding machine comprising means for supporting and rotating a workpiece, a grinding wheel mounted to be moved axially and radially relative to the workpiece, means for driving said grinding wheel, means for applying a predetermined force to the grinding wheel in a substantially radial direction relative to the workpiece, gauging means operatively associated with said workpiece to provide a signal output which is related to the difference between the actual diameter of the workpiece at the point of contact between the workpiece and grinding wheel and a datum diameter, said gauging means comprising a pneumatic device operatively positioned to provide signal output in the form of a manometric air pressure varying inversely with a function of the gap between said gauging means and the workpiece, and means actuated by said signal output for determining and apply-

ing said force to the grinding wheel in accordance with said diameter difference.

4. A grinding machine according to claim 3 wherein the gauging means comprises a caliper frame having a gauge head, an adjustable probe adapted to be maintained in substantially continuous contact with one side of the workpiece and means for supplying pressurized air through the gauge head onto the other side of the workpiece such that a variation in workpiece diameter causes an alteration in the gap between the gauge head and the workpiece which in turn causes an alteration in the air pressure in the output of the gauging means.

5. A grinding machine according to claim 1 wherein the grinding wheel is mounted on a sub-base, means mounting said sub-base on a carriage, and means mounting said carriage for axial movement relative to the workpiece, said sub-base being supported on the carriage at its end adjacent to the workpiece by pivot means and at its opposite end by a movable member of said control means.

6. A grinding machine comprising means for supporting and rotating a workpiece, a grinding wheel mounted to be moved axially and radially relative to the workpiece, said grinding wheel mounting comprising a sub-base, upon which the grinding wheel is carried, means mounting said sub-base on a carriage, and means mounting said carriage for axial movement relative to the workpiece, said sub-base being supported on the carriage at its end adjacent to the workpiece by pivot means and at its opposite end by a movable control member, means for driving said grinding wheel, means for applying a predetermined force to the grinding wheel in a substantially radial direction relative to the workpiece, gauging means operatively associated with said workpiece to provide a signal output which is related to the difference between the actual diameter of the workpiece at the point of contact between the workpiece and grinding wheel and a datum diameter, said control member being operatively connected to a pressure responsive device, and said signal output being in the form of a control air pressure produced by said gauging means and applied to said device, and means actuated by said signal output for determining and applying said force to the grinding wheel in accordance with said diameter difference.

7. A grinding machine according to claim 6 wherein said pressure responsive device is a flexible bellows vented at one side to atmosphere and there being air pressure conduit means interconnecting the other side of said device to a head in said gauging means supplying pressurized air onto said workpiece surface.

8. A grinding machine according to claim 4 wherein said grinding wheel is mounted on a support on which said caliper frame is universally mounted and said support is pivotally mounted on a carriage slidable substantially axially of said workpiece.

9. A grinding machine according to claim 5 wherein a damping device is provided for restricting pivotal movement of the sub-base relative to the carriage.

10. A grinding machine according to claim 9 wherein said damping device comprises means defining two closed spaces attached to the carriage, a double piston attached to the sub-base, a capillary tube interconnecting said closed spaces, and a liquid within said spaces such that movement of the sub-base relative to the carriage causes the transfer of liquid from one closed space to the other through the capillary tube.

11. A grinding machine according to claim 2, wherein said grinding wheel is mounted on a carriage movable substantially axially of said workpiece, a switch lever mounted on said carriage and connected to said tape reading device so as to be actuatable to advance the tape by means of signals therefrom, and a notched plate on said carriage by which the switch lever is oscillated as it travels therealong.

12. A grinding machine according to claim 11 comprising means in said tape reading machine for advancing the tape by one character on each cycle of oscillation of the switch lever.

13. A grinding machine according to claim 12, said gauging means comprising a probe contacting the workpiece surface and a gauge head discharging air under pressure against said surface and a stepping mechanism in said gauging means connected to be actuated by each character on the tape to vary the distance between the probe and the gauge head.

14. A grinding machine comprising means for supporting and rotating a workpiece about an axis, a grinding wheel for shaping the surface of said workpiece rotatably supported on an axis extending longitudinally of said workpiece, means for rotating said grinding wheel about its axis, means for moving said grinding wheel axially along said workpiece at a controlled speed, means for urging said grinding wheel into operative engagement with the surface of said workpiece during said axial movement, and means automatically responsive to the instantaneous position of said grinding wheel axially of said workpiece for metering the diameter being ground and applying the measurement for continuously automatically variably controlling the force with which said grinding wheel is urged against said workpiece whereby a predetermined contour is imparted to the workpiece as the grinding wheel moves axially therealong.

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