

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 0 903 199 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
27.11.2002 Bulletin 2002/48

(51) Int Cl.7: **B24B 5/42**, B24B 49/04

(21) Application number: **98307304.0**

(22) Date of filing: **09.09.1998**

(54) Improvements in and relating to workpiece gauging

Verbesserungen an oder in Bezug auf Messen

Perfectionnements relatifs au calibrage

(84) Designated Contracting States:
DE ES FR IT

(30) Priority: **23.09.1997 GB 9720088**
18.07.1998 GB 9815625

(43) Date of publication of application:
24.03.1999 Bulletin 1999/12

(73) Proprietor: **Unova U.K. Limited**
Aylesbury, Buckinghamshire HP20 2RQ (GB)

(72) Inventor: **Laycock, Michael**
Keighley, West Yorkshire BD20 7DH (GB)

(74) Representative: **Nash, Keith Wilfrid**
KEITH W. NASH & Co.
Pearl Assurance House
90-92 Regent Street
Cambridge CB2 1DP (GB)

(56) References cited:
WO-A-97/12724 **WO-A-97/13614**
DE-A- 4 419 656 **US-A- 5 542 188**

EP 0 903 199 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

Field of invention

[0001] This invention concerns methods and apparatus for gauging the diameter of a workpiece as per the preamble of claims 1 and 10.

[0002] An example of such a method and apparatus is disclosed by WO 97/136 14 A.

Background to the invention

[0003] Workpiece diameter has been monitored during grinding by engaging diametrically opposite regions of the workpiece by probes during the grinding process and monitoring the distance between the probes electronically. By resiliently urging the probes into contact with the workpiece so an accurate indication of the mean diameter of the workpiece is obtained and as the diameter reduces due to grinding, this is monitored and when a given diameter threshold is reached the necessary control signals are generated to adjust the grinding process accordingly.

[0004] The grinding of cylindrical surfaces necessitates the rotation of the workpiece relative to the rotating grinding wheel about the final axis required for the cylindrical ground surface. Historically the rotational speed of the workpiece has been relatively low, of the order of 20-30 rpm. With the development of the CBN grinding wheel and the higher work removal rates achievable using such rates, it is possible and desirable to rotate the workpiece at higher speeds, typically 70-80 rpm so as to obtain the benefits of the CBN grinding medium and the lower machining time.

[0005] Where the region of the workpiece which is to be ground is itself concentric of the main axis of the workpiece, so-called cylindrical grinding, the rotating workpiece can be engaged by the two fingers of a relatively fixed probe since relative to the machine frame, the workpiece remains static but for the rotational movement of its surface.

[0006] Where the region of the workpiece which is to be ground is eccentric relative to the main axis of rotation of the workpiece, the axis of the cylindrical ground region itself describes a circular motion as the workpiece is rotated about its main axis. Example of such workpiece regions are the crankpins of a crankshaft for an internal combustion engine. Each crankpin must be cylindrical about its own axis but itself is displaced by the throw of the crankshaft relative to the main axis about which the crankshaft rotates.

[0007] It is of course necessary to control the diameter of the crankpin just as accurately as the cylindrical journal bearing regions of the crankshaft and gauges have been developed for following the crankpins as they rotate about the axis of the crankshaft during the grinding operation.

[0008] At any point in the rotational movement of the

crankpin around the main axis of the crankshaft, tangential movement of the crankpin relative to the machine frame can be expressed as two orthogonal components, one parallel to the generally horizontal motion of the wheelhead and the other perpendicular thereto. The horizontal component will be zero at the two midway positions between top and bottom dead centre of the circular path described by the pin, and the vertical component of the motion will be zero at top and bottom dead centre.

[0009] By mounting the gauging device on or for movement with the wheelhead, the horizontal component of movement of the pin will be eliminated since the wheelfeed moves in sympathy with the horizontal component so as to maintain contact between the grinding wheel and the pin. However no attempt is taken to move the wheelhead vertically and the in-process gauges so far designed have attempted to accommodate the relative vertical movement between the pin and wheelhead by pivoting the gauge in some way or another so as to follow the vertical displacement of the pin above and below the mean positions as the pin rotates around the main axis of the crankshaft.

[0010] Document WO 97/13614A discloses such a known gauge, which is mounted on the wheelhead for horizontal movement but whose vertical movement is imparted by following the displacement of the crankpin.

[0011] Whilst this solution has proved to be relatively successful at low speeds of workpiece rotation, the pivoting gauges have proved to be less than accurate at higher workpiece rotational speeds now associated with CBN wheel grinding and at these speeds of rotation gauges have been observed to bounce or even lift off the rotating pin. In either event errors are introduced into the gauging and accurate diameter control of the finished workpiece is impossible.

[0012] The problem is further aggravated by the ever-increasing demands for more and more accurate grinding to size and circularity and the present invention sets out to provide an improved gauge and gauging methods which does not suffer from the problems associated with conventional gauges at higher speeds of rotation of the workpiece.

Summary of the invention

[0013] According to one aspect of the present invention, there is provided a method of in-process gauging with a gauge whilst grinding a cylindrical region of a workpiece on a grinding machine using a wheelhead mounted grinding wheel, the cylindrical region being radially offset relative to, and rotating about, the central axis of the workpiece, characterised in that the gauge is positively power driven about a circular path so as to cause the gauge to mimic in-phase the full motion of the cylindrical region about the workpiece axis.

[0014] Preferably a linkage is applied between an anchor point and the gauge extends over or below the

workpiece to locate the gauge on the opposite side thereof from the grinding wheel, so that while gauging, the gauge is suspended from the linkage remote from the grinding wheel and is moved by the linkage into engagement with the workpiece and is positively driven through the linkage so as to minimise the rotation of the offset workpiece region engaged by the gauge, about the workpiece axis, in phase therewith.

[0015] Preferably the method includes the step of compensating for the weight of the gauge and linkage so that at least during gauging, the gauge is subject only to its own inertia.

[0016] The gauge may be attached to a support which is mounted on or is driven by the wheelhead, so as to effect the movement of the gauge along the said first path, while a separate drive is provided for effecting movement of the gauge along the said second path.

[0017] Alternatively the gauge may be suspended from the end of an oscillating beam structure, pivotally mounted to a wheelhead mounted support, counterbalanced to compensate for the gauge and linkage weight, and driven by a reciprocating drive.

[0018] A significant improvement can be obtained if the radius of the arcuate path through which the gauge moves as it follows the cyclic displacement of the workpiece region being ground, is selected to be equal to the distance between the grinding wheel axis and the axis of the cylindrical workpiece region being ground when the latter is at a mid-way position between the top and bottom dead centre of its movement, and if the centre of curvature of the said arcuate path corresponds to the axis of the grinding wheel.

[0019] The invention also lies in apparatus for determining the diameter of an off-axis cylindrical workpiece region which describes a circular path around the main axis of rotation of the workpiece during a grinding process, comprising a gauge having two spaced apart fingers for engaging said region, characterised by at least one drive means to positively drive the gauge about a circular path, whereby a midpoint between the spaced apart fingers traverses the same locus as does the axis of the region to be ground, and in phase therewith, so that relative movement between the gauge and the region is limited to non-circularity or eccentricity of the region relative to its own central axis.

[0020] In order to ensure positive engagement of the fingers and the workpiece region, a small spring or other force producing device may be provided to urge the fingers towards the workpiece region to cause the latter to be lightly gripped therebetween.

[0021] In a preferred embodiment, the spring may be dispensed with if one of the fingers is L-shaped and pivoted about the apex of the gauge is moved into contact with the workpiece region, so that the leg of the L-shaped finger makes contact with the said region causing the L-shaped finger to pivot and bring the other limb of the L into contact with the said region opposite the point engaged by the other finger of the gauge.

[0022] In the event of an emergency stop a drive rapidly retracts the grinding wheel relative to the workpiece so as to disengage the two. Where the gauge is carried by a linkage which itself is rigidly attached to the wheelhead, (as is preferred), and the linkage extends over and beyond the workpiece so that the gauging fingers engage the workpiece from the side opposite to that engaged by the grinding wheel, any sudden reverse motion of the wheelhead could damage the workpiece, the gauging fingers, and/or the gauge, as well as other parts of the machine.

[0023] According therefore to an optional feature of the invention, in an emergency stop the gauge is either positively retracted away from the workpiece in a direction opposite to the movement of the wheelhead, or is permitted rapid and unimpeded movement relative to the wheelhead.

[0024] A preferred apparatus for performing a gauging method as aforesaid comprises three pivotally joined rigid struts forming with a rigid support a jointed parallelogram, the two parallel struts being pivotally joined at their inboard ends to the said rigid support, and the latter being carried by the wheelhead of a grinding machine whereby the parallelogram of struts will advance and retract in synchronous phase with the wheelhead, and wherein the strut which is pivotally joined to the outboard ends of the two parallel struts (the outboard strut) comprises a mounting for two spaced apart pivots which are displaced from the points at which the said outboard strut is pivotally joined to the two said parallel struts, from which pivots two further struts are pivotally connected, and wherein the said two further struts are pivotally joined at their outboard ends to a gauge housing having two fingers for engaging during gauging two diametrically opposite points of a cylindrical off-axis workpiece region, and drive means is provided for reciprocally pivoting the parallelogram of struts so that the gauge housing attached to the said two further struts describes a motion generally perpendicular to the motion of the wheelhead movement, whereby the two movements in combination cause the gauge housing to describe substantially the same circular path as the off-axis cylindrical region of the workpiece to be engaged by the gauge as the workpiece is rotated about its main axis.

[0025] Preferably one of the two spaced apart pivots at the outboard end of the parallelogram to which one of the said two further struts is attached lies vertically above the axis of the workpiece.

[0026] Preferably one of the said two further struts is adjustable in length and drive means is provided to achieve the alteration of the strut length so that relative movement can be obtained between the gauge and the non-adjustable strut therefore the parallelogram of struts.

[0027] In an alternative arrangement the support for the parallelogram of struts may be separate from the wheelhead and movement of the said parallelogram of

struts in sympathy with the wheelhead is achieved by a separate servo drive responsive to control signals derived from the wheelfeed signals and/or from signals from an encoder associated with the headstock.

[0028] According to a preferred feature of the invention, the gauge includes two parallel spaced apart fingers for lightly engaging diametrically opposite regions of the workpiece region, and a further workpiece engaging element which is located approximately mid-way between the said two fingers and is displaced relative to a line joining the said two fingers by a distance commensurate with the radius of the workpiece region which is to be gauged, so that the said element will engage a point on the surface of the workpiece region which is diametrically opposite the point of contact with the grinding wheel.

[0029] The workpiece engaging element may be a separate member independently movable relative to the housing and therefore to the two fingers.

[0030] Electrical signals corresponding to the mean diameter determined upon initial engagement between the fingers and the workpiece region, and subsequently to changes in diameter during grinding, may be derived from one or more transducers associated with the fingers. The signals may be transmitted as feedback signals to a computer adapted to control the overall operation of the machine.

[0031] In accordance with a preferred feature of the invention, the pivot for the non-extensible strut joining the outboard strut of the parallelogram of struts to the gauge housing, defines a pivot axis which is parallel to the axis of the off-axis cylindrical region of the workpiece being ground, and remains generally vertically thereabove as a consequence of its movement with the wheelhead.

[0032] The extensible strut may comprise at least in part a pneumatic cylinder, movement of the piston therein producing the variation in overall length of the strut, and control means is provided for supplying air to the cylinder to extend or retract the cylinder as required.

[0033] Alteration of the length of the strut pivotably moves the gauge housing about the end of the non-extensible strut and therefore relative to the parallelogram of rigid struts, and in turn relative to the workpiece region to be gauged, to facilitate the engagement and disengagement of the latter by the gauge fingers.

[0034] A single acting cylinder with spring return may be employed, the latter acting to shorten the length of the strut if air pressure is removed. If a strong spring is employed, this feature may be used to retract the gauge in an emergency stop scenario.

[0035] Preferably torque generating means is provided so that a turning movement is produced about the pivot of at least one of the parallel struts of the said parallelogram, the direction and magnitude of which is such as to compensate for the opposite turning movement about that pivot created by the mass of the gauge linkage.

[0036] In one arrangement, one of the two parallel struts of the parallelogram extends beyond the pivot point where it is attached to the wheelhead mounted support, and the turning moment of the extended section of the strut is adapted to generally counterbalance the weight of the gauge and supporting structure, so that a very small force is needed to reciprocally pivot the array of struts and the gauge (and/or to move the gauge relative to the struts for engagement and disengagement of the workpiece region), and no additional force is required to counterbalance the gravitational forces acting about the pivot occasioned by the weight of the gauge and the supporting structure.

[0037] In CNC grinding, the headstock rotates the workpiece and an encoder is normally associated with the headstock which allows instantaneous rotational positional information of the workpiece to be obtained and therefore additionally information about the rotational position of the region of the workpiece which is being ground where this is off-axis. Information from the headstock drive, and in particular the encoder therefor, allows complete synchronisation of the machine and the region being ground, and in the same way as accurate positioning of the wheelhead can be achieved using appropriate servo control signals and servo motors, so a servo drive associated with the gauge support structure (such as a parallelogram of struts as described herein), and acting thereon to reciprocally move the struts so that in combination with the advance and retract movement of the wheelhead the gauge is caused to describe a circular movement, the servo drive can be synchronised with the rotation of the workpiece using the encoder output signals from the headstock.

[0038] In this way the gauge can be maintained in strict phase with the rotational movement of the headstock, and therefore the workpiece, so that any variation in instantaneous speed of rotation around the circular path can be detected and transmitted into the movement of the gauge so as to remove any unwanted force between the workpiece and the gauging fingers.

[0039] When incorporating this feature, a gauge constructed in accordance with the invention becomes quite distinct from any previous gauge since the gauge fingers can be driven in perfect synchronism and phase with the rotating off-axis workpiece region which is to be gauged and no force needs to act between the gauging fingers and the gauged surface to cause the gauge to follow the movement of the workpiece region.

[0040] Where the gauge is carried at the lower end of a pivoted strut and needs to be able to accommodate a small amount of movement caused by non-circularity etc, the gauge housing is preferably attached to the lower end of the said strut, through a lost motion connection.

[0041] An alternative arrangement for achieving the rotatable movement of the gauge comprises a pair of rotating cranks mounted for rotation about two vertically spaced apart axes, parallel to the main axis of the workpiece, and joined by a rigid link which extends down-

wardly below the lower of the two cranks where it is secured to a gauge housing having fingers for engaging diametrically opposite regions around an off-axis cylindrical workpiece region which is rotating about the main axis of the workpiece during grinding, wherein the radius of the cranks and the speed of rotation is selected so as to correspond to the radius of the circular motion of the said off-axis cylindrical region, and to the rotational speed of the said region around the main axis of the workpiece, so that the gauge describes the same circular path in phase with the movement of the said region around the workpiece axis.

[0042] Other optional features of the invention are defined in the dependent claims.

[0043] The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a side view of a first embodiment of the invention;

Figure 2 is a front view of the embodiment of figure 1 (in the direction of arrow II in Figure 1);

Figure 3 is a plan view of parts of the apparatus of Figure 1;

Figure 4 is a schematic side view of another embodiment of the invention; and

Figure 5 is a similar view of a further embodiment.

[0044] In Figures 1 to 4, a wheelhead is shown at 10 and the unworn and worn perimeters of a CBN grinding wheel 16 are denoted by 12 and 14 respectively.

[0045] The corresponding positions of a crankpin to be ground by the grinding wheel 16 are denoted by 18 and 20 respectively. These correspond to the unworn and worn conditions of the CBN wheel and in accordance with the invention a gauge or probe 22 having an upper composite finger 24 and lower movable finger 26 is shown engaging the pin in the position 18 of the pin at the beginning of the life of the wheel.

[0046] Pads 28 and 30 on the composite finger 24 engage two regions of the pin separated by a right angle, and a pad 32 on the finger 26 engages the pin diametrically opposite the region engaged by pad 28. The probe 22 includes one or more transducers (not shown) for determining the spacing between the subsequent movement of the fingers, and therefore the diameter, and changes in the diameter, of the pin being ground.

[0047] The probe is itself pivotally attached at 34 to the lower end of a rigid strut or arm 36 the upper end of which is pivotally attached at 38 to a closure plate 40. A second separate pivot point 42 on the plate 40 provides the upper mounting point for a pneumatic piston and cylinder 44 the outboard end of the piston rod being pivotally connected at 46, at the lower end of the rigid strut 36.

[0048] The plate 40 provides a closure to a parallelogram of struts the longer sides of which are made up of two struts 48 and 50, which are pivotally attached to the plate 40 at 52 and 54 respectively. At their opposite ends they are pivotally attached to an upright rigid support member 56 at 58 and 60 respectively. The support 56 is mounted on the wheelhead 10 and moves therewith.

[0049] A servo drive 64 reciprocally pivots the rigid strut 50 about the pivot axis 60 so as to reciprocally raise and lower the probe 22 and since the motion is arcuate, the mid-position between the two pads 28 and 32 (denoted by reference numeral 66) will in fact describe an arcuate path as identified by 68. By making the effective centre of the arcuate path 68 the same as the centre of rotation of the wheel 16 (denoted by reference numeral 70), so the arcuate path described by the centre of the rotating workpiece region being ground as it maintains contact with the wheel 16, as the latter advances and retracts, will correspond substantially with the arcuate path 68 described by the mid-position of the pads 28 and 32.

[0050] In this way the force acting between the pads 28, 30, 32 and pin being ground is restricted to that generated by the resilience within the probe 22 and it is only necessary for the probe to counteract inertia forces due to out of roundness and eccentricity and the like of the workpiece region being ground. It is not necessary for reactive forces to be accommodated or generated so as to maintain contact between the pad and the workpiece.

[0051] In order to accommodate emergency retract, a pressure relief valve 72 is provided to vent the airline supplying the pneumatic cylinder 44 in an emergency.

[0052] In addition or alternatively, the cylinder 44 may be vented at both ends as soon as the probe pads 28, 30 and 32 are in contact with the workpiece region to be ground, so that in the event of an emergency retract, the cylinder 44 presents no resistance to the rapid inward movement of the piston (not shown) thereby permitting rapid relative movement between the wheelhead and the probe, as the wheel is retracted.

[0053] A counterbalance weight 74 is carried at the end of an extension 62 of the arm 48.

[0054] Figures 2 and 3 show how the support 56 can be mounted laterally of a grinding wheel housing 76. Similar reference numerals are employed in Figures 2 and 3 to denote the same parts as shown in Figure 1 and by comparing Figures 1 and 3 it will be seen that the two arms 48 and 50 are bent approximately midway along their length to cause the outboard ends of 48 and 50 to finish up generally opposite the grinding wheel housing 76, but displaced by a suitable distance from the wheel 16 to allow for the gauge housing 22 and its probes 24, 26 to be mounted thereon from the arms 36, 44, beyond the region occupied by the crankshaft workpiece whose pins are to be ground and gauged.

[0055] The bends are denoted by reference numerals 78, 80 in Figures 2 and 3.

[0056] A lost motion connection is provided between

the arm 36 and the housing 22, which pivots relative to 36 at 34. To this end a finger 82 extends rearwardly and upwardly from the housing 22 and includes a locking nut and threaded adjuster screw 84 which can be rotated so as to alter a gap between the end of the screw and the arm 36. By careful adjustment the screw end can be held one or two millimetres off the arm 36 when the gauge feelers 28, 32 engage a pin. The gauge assembly then "floats" if the cylinder 44 is depressurised. The weight of the housing 22 will introduce a turning movement about 34 when the feelers are disengaged from the pin, but clockwise pivoting of the housing 22 about 34 is restricted by engagement of the screw 84 with the arm 36.

[0057] Re-engagement of another pin by the gauge, causes the housing 22 to rotate in a counter clockwise sense as the two feelers 28, 32 grip the pin, causing the screw 84 to move away from the arm 36 again, to once again produce the operating gap.

[0058] In the event of an emergency retract of the wheelhead, so as to disengage the wheel 16 from the pin being ground, initial movement of the gauge in the same direction as the wheel is accommodated by sliding of the feelers 28, 32 relative to the pin, but then the reaction force acting through pad 30 causes the cylinder 44 to collapse permitting relative movement of support member 56 and the arm 36 to occur. The lower end of arm 36 moves upwardly it pivots about 38. This shifts the gauge backwardly and upwardly away from the pin, so preventing damage to the workpiece and/or the gauge.

[0059] In Figure 4 the two arms 48, 50 are replaced by a triangular assembly 86 mounted on the wheelhead adjacent the wheel housing and carrying a vertical slideway on which a linear motion drive 90 is carried. The latter is programmable under computer control to slide up and down the slideway 88 as required to raise and lower a plate 92 carried by the drive unit. The drive 90 may be pneumatic or electromagnetic.

[0060] The remainder of the gauge support is similar to that shown in Figures 1 to 3 and the component parts are similarly identified. Thus the gauge housing 22' is positioned to the lower end of an arm 36' at 34' and the upper end of arm 36' is pivoted to the plate 90 at 38. Likewise a pneumatic piston and cylinder 44' is pivoted at 42' and 46'.

A similar stop 84 and arm 82 is provided to provide lost motion between arm 36' and housing 22' as described in relation to Figure 1.

[0061] The linear movement of drive 90 and plate 92 is translated into linear vertical movement of the housing 22' and any relative horizontal movement between the fingers 24', 26' and the pin 20' is accommodated by the long flat pads 28', 32' as before.

[0062] The drive 90 is programmed so as to move in synchronism with the wheelfeed and crankshaft rotation, so that the gauge follows the circular path of the pin being ground.

[0063] Figure 5 shows how two rotating cranks 94, 96 can transmit a simple harmonic motion via rigid connecting rod 98 to a gauge housing 22" pivotally attached at 100 to the lower end of the rod 98, with lost motion provided by an arm 82" and screw 84", similar to the similar items described with reference to Figure 1 and Figure 4.

[0064] By appropriately driving the cranks, so the gauge will describe a circular path at a desired frequency and speed - which can vary during the circular path if desired. A computer (not shown) suitably programmed, provides the control signals.

[0065] The cranks are carried on a slide 102, itself slidable relative to a support 104 attached to the machine structure (as opposed to the wheelhead) and also be capable of horizontal or rotational displacement relative to the machine structure for engaging and disengaging the gauge fingers 24", 26" from the workpiece W. Horizontal movement of the slide 102 is also under computer control, and is provided to allow for initial engagement and final disengagement of the fingers 24", 26" and the workpiece W.

Claims

1. A method of in-process gauging with a gauge (22) whilst grinding a cylindrical region of a workpiece (20) on a grinding machine using a wheelhead mounted grinding wheel (16), the cylindrical region being radially offset relative to, and rotating about, the central axis of the workpiece, **characterised in that** the gauge (22) is positively power driven about a circular path so as to cause the gauge to mimic in-phase the full motion of the cylindrical region about the workpiece axis.
2. A method according to claim 1 further comprising the step of applying a linkage (36,40, 48, 50) between an anchor point and the gauge (22), the linkage extending over or below the workpiece region to locate the gauge on the opposite side thereof from the grinding wheel, so that during gauging the gauge is suspended from the linkage remote from the grinding wheel, is moved by the linkage into engagement with the region to be gauged, and is positively driven through the linkage so as to rotate about the workpiece axis in phase with the rotation of the region therearound.
3. A method according to claim 2 which includes the step of compensating for the weight of the gauge and linkage, so that at least during gauging, the gauge is subject only to its own inertia.
4. A method according to any one of claims 1 to 3 further comprising the steps of engaging opposite sides of said region by a pair of gauging fingers (24, 26) of the gauge to determine the distance between

the fingers and therefore the diameter of the gauged region, moving the fingers along a first path parallel to the movement of the wheelhead (10) in synchronism and phase therewith so that relative movement parallel to the said first path between said region and the gauge is substantially eliminated, and moving the gauge along a second path (68) orthogonal to the first path and in synchronism with the movement along the first path, whereby the gauge describes a circular path around the workpiece axis whose radius is similar to that of the circular path of the region being ground and is controlled so as to be in phase with the rotation thereof.

5. A method according to claim 4 comprising the step of attaching the gauge (22) to a support (56) mounted on or driven by the wheelhead, so as to effect the movement of the gauge along said first path, while providing a separate drive for effecting movement of the gauge along said second path.
6. A method according to claim 4 comprising the step of suspending the gauge from the end of an oscillating beam structure which is pivotally mounted to a wheelhead mounted support (56), counterbalancing the structure to compensate for the gauge and linkage weight, and applying a reciprocating drive.
7. A method according to any one of claims 4 to 6 in which the second path (68) of the gauge is arcuate, being selected to be equal to the distance between the grinding wheel axis and the axis of said region when the latter is at a mid-way position (66) between the top and bottom dead centre of its movement.
8. A method according to claim 7 in which the centre of curvature of said arcuate path (68) corresponds to the axis (70) of the grinding wheel.
9. A method according to any one preceding claim in which, in the event of an emergency stop, the gauge is either positively retracted away from the workpiece in a direction opposite to the movement of the wheelhead, or is permitted rapid and unimpeded movement relative to the wheelhead.
10. Apparatus for determining the diameter of an off-axis cylindrical workpiece region (20) which describes a circular path around the main axis of rotation of the workpiece during a grinding process, comprising a gauge (22) having two spaced apart fingers (24, 26) for engaging said region, **characterised by** at least one drive means (64) to positively drive the gauge (22) about a circular path, whereby a midpoint between the spaced apart fingers traverses the same locus as does the axis of the region (20) to be ground, and in phase there-

with, so that relative movement between the gauge and the region is limited to non-circularity or eccentricity of the region relative to its own central axis.

11. Apparatus according to claim 10 further comprising a small spring or other force producing device for urging the fingers towards the region, causing the latter to be lightly gripped between the fingers.
12. Apparatus according to claim 10 in which one of the fingers (24) of the gauge (22) is L-shaped and pivoted about its apex for movement into contact with the workpiece region, so that one limb (30) of the L-shaped finger makes contact with the said region causing the L-shaped finger to pivot and bring the other limb of the L into contact with the said region opposite the point engaged by the other finger (26) of the gauge.
13. Apparatus according to any one of claims 10 to 12 for use on a grinding machine, comprising three pivotally joined struts (40, 48, 50) forming with a rigid support (56) a jointed parallelogram, the two parallel struts (48, 50) being pivotally joined at their inboard ends to the rigid support (56), and the latter being carried by means moveable with a wheelhead (10) which incorporates a grinding wheel (16), whereby the parallelogram of struts advances and retracts in synchronous phase with the wheelhead, and wherein the outboard strut (40) which is pivotally joined to the outboard ends of the two parallel struts comprises a mounting for two spaced apart pivots, from which first and second struts (36, 44) are pivotally connected, wherein the first strut is pivotally joined at its outboard end to said gauge (22), and the second strut is connected to the outboard end of the first strut (36) at a pivot adjacent to the pivot for said gauge, and wherein said drive means (64) is connected for reciprocally pivoting the parallelogram of struts so that the gauge describes a motion generally perpendicular to the motion of the wheelhead, whereby during rotation of the workpiece region (20) the two movements in combination cause the gauge to describe substantially the same circular path as the workpiece region engageable by the gauge.
14. Apparatus according to claim 13 in which one of said spaced apart pivots (38) to which said first strut (36) is attached, lies vertically above the axis of the workpiece region (20).
15. Apparatus according to claim 13 or claim 14 in which said second strut is adjustable in length, and drive means (44) is provided to achieve the alteration of its length so that relative movement can be obtained between the gauge (22) and the first strut (36), and therefore the parallelogram of struts (40,

48, 50).

16. Apparatus according to any one of claims 13 to 15 in which said rigid support (56) is separate from the wheelhead (10) and movement of said parallelo-
gram of struts in sympathy with the wheelhead is achieved by a separate servo drive responsive to control signals derived from wheelfeed signals and/or from signals from an encoder associated with a headstock for mounting the workpiece.
17. Apparatus according to any one of claims 13 to 16 in which the two fingers (24, 26) of the gauge (22) lightly engage diametrically opposite points of the workpiece region (20), and a further workpiece engaging element (30) is located approximately mid-way between the two fingers and displaced relative to a line joining the two fingers by a distance commensurate with the radius of the region to be gauged, to enable said element to engage a point on the surface of the workpiece region which is diametrically opposite the point of grinding contact with the region.
18. Apparatus according to claim 17 in which said element (30) is a separate member independently movable relative to the gauge and therefore to the two fingers.
19. Apparatus according to any one of claims 10 to 18 further comprising one or more transducers associated with the fingers from which are derived electrical signals, corresponding to the mean diameter determined upon initial engagement between the fingers and the workpiece region, and subsequently corresponding to changes in diameter during grinding.
20. Apparatus according to any one of claims 13 to 19 in which the pivot between the first strut (36) and the outboard strut (40) defines a pivot axis (38) which is parallel to the axis of said workpiece region and remains generally vertically thereabove as a consequence of its movement with the wheelhead (10).
21. Apparatus according to any one of claims 13 to 20 in which the second strut comprises at least in part a pneumatic cylinder (44), movement of a piston therein producing the variation in overall length of the strut, and further comprising control means for supplying air along an airline to the cylinder to extend or retract the cylinder as required.
22. Apparatus according to claim 21 in which the cylinder (44) is a single acting cylinder with a return spring, the spring acting to shorten the length of the strut if air pressure is removed.

23. Apparatus according to any one of claims 13 to 22 further comprising torque generating means for producing a turning movement about the pivot of at least one of the parallel struts (48) of the said parallelogram, the direction and magnitude of which is such as to compensate for the opposite turning movement about that pivot created by the weight of the gauge and supporting structure.
24. Apparatus according to any one of claims 13 to 22 in which one of the two parallel struts (48) has an extended section (62) beyond the pivot point (58) where it is attached to the rigid support (56), and the turning moment of the extended section (62) of the strut is adapted to generally counterbalance the weight of the gauge and supporting structure, so that a reduced force is needed to reciprocally pivot the gauge and structure.
25. Apparatus according to any one of claims 10 to 24 in which said drive (64) means comprises a reciprocating servo drive imparting to the gauge a simple harmonic motion with frequency and amplitude control.
26. Apparatus according to any one of claims 13 to 25 comprising a further drive between the wheelhead and said rigid support for the gauge support structure, which itself is also under computer control, to allow for fine tuning of the advance and retract movement of the gauge in the direction of the wheelhead movement.
27. Apparatus according to any one of claims 13 to 24 in which the workpiece is mounted on a headstock with which an encoder is associated to allow instantaneous rotational positional information of the workpiece to be obtained, and in which said drive means (64) comprises a servo drive associated with the gauge support structure and acting thereon to reciprocally move the parallel struts, so that in combination with the advance and retract movement of the wheelhead the gauge is caused to describe a circular movement, and in which the servo drive is synchronised with the rotation of the workpiece using output signals from the headstock encoder.
28. Apparatus according to any one of claims 13 to 27 in which the gauge is attached to the lower end of the first strut through a lost motion connection (82, 84).
29. Apparatus according to any one of claims 13 to 28 in which said means moveable with a wheelhead and said drive means, which jointly produce a circular movement of the gauge, are constituted by a pair of rotating cranks (94, 96) mounted for rotation about two vertically spaced apart axes, parallel to

the main axis of the workpiece (W), and joined by a rigid link (98) which extends downwardly below the lower of the pair of cranks where it is secured to the gauge (22"), wherein the radius of the cranks and the speed of rotation is selected so as to correspond to the radius of the circular motion of the workpiece region, and to the rotational speed of the region around the main axis of the workpiece (W), so that the gauge describes the same circular path in phase with the circular motion of the workpiece region.

Patentansprüche

1. Verfahren zum Messen beim Bearbeitungsvorgange mit Hilfe einer Meßvorrichtung (22) während des Schleifens eines zylindrischen Bereiches eines Werkstückes (20) auf einer Schleifmaschine unter Verwendung einer auf einem Schleifkopf befestigten Schleifscheibe (16), wobei der zylindrische Bereich in radialer Richtung relativ zur zentralen Achse des Werkstückes versetzt ist und um diese zentralen Achse rotiert, **dadurch gekennzeichnet, dass** die Meßvorrichtung (22) positiv in einem kreisförmigen Pfad angetrieben wird, derart, dass die Meßvorrichtung im Gleichlauf die volle Bewegung des zylindrischen Bereiches um die Werkstückachse nachahmt.
2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** eine Verbindung (36, 40, 48, 50) zwischen einer Verankerungsstelle und der Meßvorrichtung (22) vorgesehen wird, dass die Verbindung sich oberhalb oder unterhalb des Werkstückbereiches erstreckt, um die Meßvorrichtung auf der entgegengesetzten Seite in bezug auf die Schleifscheibe so zu positionieren, dass während des Meßvorganges die Meßvorrichtung an der Verbindung entfernt von der Schleifscheibe aufgehängt ist, durch die Verkettung in Eingriff mit dem zu messenden Bereich bewegt wird und über die Verbindung positiv angetrieben wird, derart, dass sie um die Werkstückachse in Phase mit der Drehung des darum herum befindlichen Bereiches rotiert.
3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** das Gewicht der Meßvorrichtung und der Verbindung kompensiert wird, derart, dass mindestens während des Messens die Meßvorrichtung nur ihrer eigenen Trägheit ausgesetzt wird.
4. Verfahren nach einem der Ansprüche 1 - 3, **dadurch gekennzeichnet, dass** entgegengesetzte Seiten des Bereiches durch ein Paar von Messfingern (24, 26) der Meßvorrichtung beaufschlagt werden, um den Abstand zwischen den Fingern und

damit den Durchmesser des gemessenen Bereiches zu bestimmen, dass die Finger längs eines ersten Pfades parallel zur Bewegung des Schleifkopfes (10) synchron und in Phase damit bewegt werden, so dass eine Relativbewegung parallel zu dem ersten Pfad zwischen diesem Bereich und der Messvorrichtung weitgehend eliminiert wird, und dass die Messvorrichtung längs eines zweiten Pfades (68) im rechten Winkel zum ersten Pfad und synchron mit der Bewegung längs des ersten Pfades bewegt wird, wobei die Messvorrichtung einen kreisförmigen Pfad um die Werkstückachse beschreibt, dessen Radius ähnlich dem des kreisförmigen Pfades des zu schleifenden Bereiches ist und so gesteuert wird, dass sie in Phase mit der Rotation ist.

5. Verfahren nach Anspruch 4, **dadurch gekennzeichnet, dass** die Meßvorrichtung (22) mit einem Support (56) verbunden wird, der auf dem Schleifkopf befestigt oder von diesem angetrieben wird, um die Bewegung der Meßvorrichtung längs des ersten Pfades zu erzielen, während ein getrennter Antrieb zur Erzielung einer Bewegung der Meßvorrichtung längs des zweiten Pfades vorgesehen wird.
6. Verfahren nach Anspruch 4, **dadurch gekennzeichnet, dass** die Meßvorrichtung an dem Ende eines oszillierenden Balkensystems aufgehängt wird, das schwenkbar auf einem mit dem Schleifkopf verbundenen Support (56) befestigt ist, wobei das Balkensystem abgeglichen wird, um das Gewicht der Meßvorrichtung und der Verbindung zu kompensieren, und wobei ein hin- und hergehender Antrieb angelegt wird.
7. Verfahren nach einem der Ansprüche 4 - 6, bei dem der zweite Pfad (68) der Meßvorrichtung gekrümmt ausgebildet und so ausgewählt wird, dass er gleich dem Abstand zwischen der Schleifscheibenachse und der Achse dieses Bereiches ist, wenn der Bereich eine Mittenposition (66) zwischen dem oberen und dem unteren Totpunkt seiner Bewegung einnimmt.
8. Verfahren nach Anspruch 7, bei dem die Mitte der Kurve des gekrümmten Pfades (68) der Achse (70) der Schleifscheibe entspricht.
9. Verfahren nach einem der vorausgehenden Ansprüche, bei dem im Falle eines Not-Sperrvorganges die Meßvorrichtung entweder positiv von dem Werkstück in einer Richtung entgegengesetzt zu der Bewegung des Schleifkopfes zurückgezogen wird, oder eine rasche und ungehinderte Bewegung relativ zum Schleifkopf zugelassen wird.

10. Vorrichtung zum Bestimmen des Durchmessers eines achsversetzten zylindrischen Werkstückbereiches (20), das einen kreisförmigen Pfad um die Haupt-Drehachse des Werkstückes während eines Schleifvorganges beschreibt, mit einer Messvorrichtung (22) mit zwei im Abstand voneinander versetzten Fingern (24, 26) für den Eingriff in diesen Bereich, **gekennzeichnet durch** mindestens eine Antriebsvorrichtung (64) zum positiven Antreiben der Messvorrichtung (22) über einen kreisförmigen Pfad, wobei ein Mittelpunkt zwischen den beabstandeten Fingern den gleichen geometrischen Ort wie die Achse des zu schleifenden Bereiches (20) und in Phase damit durchquert, so dass eine Relativbewegung zwischen der Messvorrichtung und dem Bereich auf eine von der Kreisform abweichende Form oder Exzentrizität des Bereiches relativ zur eigenen zentralen Achse beschränkt ist.
11. Vorrichtung nach Anspruch 10, **gekennzeichnet durch** eine kleine Feder oder eine andere Kraft erzeugende Vorrichtung, die die Finger gegen den Bereich drückt, wobei der Bereich leicht zwischen den Fingern erfasst wird.
12. Vorrichtung nach Anspruch 10, bei der einer der Finger (24) der Messvorrichtung (22) L-förmig ausgebildet und um seinen Scheitel schwenkbar angeordnet ist, damit er in Kontakt mit dem Werkstückbereich gebracht werden kann, derart, dass ein Schenkel (30) des L-förmigen Fingers Kontakt mit dem Bereich gibt und der L-förmige Finger verschwenkt wird sowie den anderen Schenkel des L in Kontakt mit dem Bereich gegenüber der Stelle gebracht wird, die von dem anderen Finger (26) der Messvorrichtung beaufschlagt wird.
13. Vorrichtung nach einem der Ansprüche 10 - 12 zur Verwendung bei einer Schleifmaschine, **gekennzeichnet durch** drei schwenkbar miteinander verbundene Streben (40, 48, 50), die zusammen mit einem starren Support (56) ein gelenkig verbundenes Parallelogramm bilden, die beiden parallelen Streben (48, 50) schwenkbar an ihren Innenseiten mit dem starren Support (56) verbunden sind und letzterer von einer Vorrichtung aufgenommen wird, die mit einem Schleifkopf (10) verschiebbar ist, der ein Schleifrad (16) aufnimmt, wobei das Parallelogramm von Streben in Phase synchron mit dem Schleifkopf vorgeschoben und zurückgezogen wird, und wobei die äußere Strebe (40), die schwenkbar mit den äußeren Enden der beiden parallelen Streben verbunden ist, eine Befestigung für zwei voneinander beabstandete Schwenkstellen aufweist, von denen aus erste und zweite Streben (36, 44) schwenkbar miteinander verbunden ist, wobei die erste Strebe schwenkbar an ihrem äußeren Ende mit der Messvorrichtung (22) und die zweite Strebe mit dem äußeren Ende der ersten Strebe (36) an einer Schwenkstelle in der Nähe der Schwenkstelle für die Messvorrichtung verbunden ist und wobei die Antriebsvorrichtung (64) zur hin- und hergehenden Verschwenkung des Parallelogramms von Streben so verbunden ist, dass die Messvorrichtung eine Bewegung etwa rechtwinklig zu der Bewegung des Schleifkopfes durchführt, wobei während einer Rotation des Werkstückbereiches (20) die beiden Bewegungen in Kombination bewirken, dass die Messvorrichtung im wesentlichen den gleichen kreisförmigen Pfad beschreibt wie der Werkstückbereich, der von der Messvorrichtung beaufschlagbar ist.
14. Vorrichtung nach Anspruch 13, bei der eine der beabstandeten Schwenkstellen (38), mit der die erste Strebe (36) verbunden ist, vertikal über der Achse des Werkstückbereiches (20) liegt.
15. Vorrichtung nach Anspruch 13 oder 14, bei der die zweite Strebe längenverstellbar ausgebildet ist und eine Antriebsvorrichtung (44) vorgesehen ist, mit der die Änderung der Länge vorgenommen wird, so dass eine Relativbewegung zwischen der Messvorrichtung (22) und der ersten Strebe (36) und damit des Parallelogramms von Streben (40, 48, 50) erhalten werden kann.
16. Vorrichtung nach einem der Ansprüche 13 - 15, bei der der starre Support (56) getrennt von dem Schleifkopf (10) angeordnet ist und eine Bewegung des Parallelogramms von Streben in Übereinstimmung mit dem Schleifkopf durch einen getrennten Servoantrieb erzielt wird, der auf Steuersignale anspricht, die von den Schleifkopf-Signalen und/oder von Signalen aus einem Codierer, der einem Spindelstock zur Befestigung des Werkstückes zugeordnet ist, abgeleitet werden.
17. Vorrichtung nach einem der Ansprüche 13 - 16, bei der die beiden Finger (24, 26) der Messvorrichtung (22) entgegengesetzte Stellen des Werkstückbereiches (20) leicht beaufschlagen und ein weiteres Werkstück-Eingriffselement (30) etwa in der Mitte zwischen den beiden Fingern angeordnet und relativ zu einer Linie versetzt angeordnet ist, die die beiden Finger in einem Abstand verbindet, der mit dem Radius des zu messenden Bereiches übereinstimmt, damit das Element in die Lage versetzt wird, einen Punkt auf der Oberfläche des Werkstückbereiches zu beaufschlagen, der diametral gegenüber der Stelle des Schleifkontaktes mit dem Bereich liegt.
18. Vorrichtung nach Anspruch 17, **dadurch gekennzeichnet, dass** das Element (30) ein getrenntes Bauteil ist, das unabhängig relativ zu der Messvor-

richtung und deshalb zu den beiden Fingern verschiebbar ist.

19. Vorrichtung nach einem der Ansprüche 10 - 18, **gekennzeichnet durch** ein oder mehrere Wandler, die den Fingern zugeordnet sind, von denen elektrische Signale abgeleitet werden, die dem mittleren Durchmesser, der bei einem anfänglichen Eingriff zwischen den Fingern und dem Werkstückbereich festgelegt wird, und im Anschluss daran Änderungen des Durchmessers während des Schleifens entsprechen. 5
20. Vorrichtung nach einem der Ansprüche 13 - 19, bei der die Schwenkstelle zwischen der ersten Strebe (36) und der äußeren Strebe (40) eine Schwenkachse (38) festlegt, die parallel zur Achse des Werkstückbereiches liegt und im wesentlichen vertikal darüber als Folge ihrer Bewegung mit dem Schleifkopf (10) verbleibt. 10 15
21. Vorrichtung nach einem der Ansprüche 13 - 20, bei der die zweite Strebe mindestens zum Teil einen pneumatischen Zylinder (44) aufweist, die Bewegung eines Kolbens im Zylinder die Änderung der Gesamtlänge der Strebe ergibt, und ferner eine Steuervorrichtung vorgesehen ist, die Luft längs einer Luftleitung zum Zylinder einspeist, um den Zylinder in der gewünschten Weise aus- oder einzufahren. 25 30
22. Vorrichtung nach Anspruch 21, bei der der Zylinder (44) ein einfach wirkender Zylinder mit einer Rückföhrfeder ist, wobei die Feder eine Verkürzung der Länge der Strebe bewirkt, wenn Luftdruck entfernt wird. 35
23. Vorrichtung nach einem der Ansprüche 13 - 22, **gekennzeichnet durch** eine ein Drehmoment erzeugende Vorrichtung zur Erzielung einer Drehbewegung um die Schwenkstelle wenigstens einer der parallelen Streben (48) des Parallelogramms, wobei Richtung und Größe dieser Bewegung so bemessen sind, dass die entgegengesetzte Drehbewegung um die Schwenkstelle kompensiert wird, die **durch** das Gewicht der Messvorrichtung und der Traganordnung hervorgerufen wird. 40 45
24. Vorrichtung nach einem der Ansprüche 13 - 22, bei der eine der beiden parallelen Streben (48) einen verlängerten Abschnitt (62) über die Schwenkstelle (58) hinaus, an der er mit dem starren Support (56) befestigt ist, besitzt, und das Drehmoment des verlängerten Abschnittes (62) der Strebe in der Lage ist, dem Gewicht der Messvorrichtung und der Traganordnung entgegen zu wirken, so dass eine verringerte Kraft erforderlich ist, um die Messvorrichtung und die Anordnung hin- und her zu schwenken. 50 55
25. Vorrichtung nach einem der Ansprüche 10 - 24, bei der die Antriebsvorrichtung (64) einen hin- und hergehenden Servoantrieb aufweist, der der Messvorrichtung eine einfache harmonische Bewegung mit Frequenz- und Amplitudensteuerung erteilt.
26. Vorrichtung nach einem der Ansprüche 13 - 25, **gekennzeichnet durch** einen weiteren Antrieb zwischen dem Schleifkopf und dem starren Support für die Abstützvorrichtung der Messvorrichtung, die selbst rechnergesteuert ist, damit eine Feinabstimmung der Vorschub- und Rückziehbewegung der Messvorrichtung in Richtung der Schleifkopfbewegung ermöglicht wird.
27. Vorrichtung nach einem der Ansprüche 13 - 24, bei der das Werkstück auf einem Spindelstock befestigt ist, dem ein Codierer zugeordnet ist, der eine augenblickliche Drehpositions-Information des zu erzielenden Werkstückes ermöglicht, und bei der eine Antriebsvorrichtung (64) einen Servoantrieb aufweist, der der Abstützvorrichtung der Messvorrichtung zugeordnet ist und auf sie in der Weise einwirkt, dass sie die parallelen Streben hin- und herbewegt, damit in Verbindung mit der Vorschub- und Rückziehbewegung des Schleifkopfes die Messvorrichtung dazu gebracht wird, eine kreisförmige Bewegung zu beschreiben, und bei der der Servoantrieb mit der Rotation des Werkstückes unter Verwendung von Ausgangssignalen aus dem Spindelstock-Codierer synchronisiert ist.
28. Vorrichtung nach einem der Ansprüche 13 - 27, bei der die Messvorrichtung mit dem unteren Ende der ersten Strebe über eine Totgang-Verbindung (82, 84) befestigt ist.
29. Vorrichtung nach einem der Ansprüche 13 - 28, bei der die Vorrichtung, die mit einem Schleifkopf und der Antriebsvorrichtung, welche gemeinsam eine kreisförmige Bewegung der Messvorrichtung ergeben, durch zwei rotierende Kurbeln (94, 96) gebildet sind, die drehbar um zwei vertikal versetzte Achsen parallel zur Hauptachse des Werkstückes (W) befestigt und über eine starre Gelenkverbindung (98) miteinander verbunden sind, die sich nach abwärts unter die untere der beiden Kurbeln erstreckt, wo sie mit der Messvorrichtung (22") befestigt ist, wobei der Radius der Kurbeln und die Rotationsgeschwindigkeit so gewählt sind, dass sie dem Radius der Kreisbewegung des Werkstückbereiches und der Drehgeschwindigkeit des Bereiches um die Hauptachse des Werkstückes (W) entsprechen, so dass die Messvorrichtung den gleichen kreisförmigen Pfad in Phase mit der Kreisbewegung des Werkstückbereiches beschreibt.

Revendications

1. Procédé de calibrage en cours de fabrication avec un calibre (22) tout en meulant une région cylindrique d'une pièce (20) sur une meuleuse utilisant une meule montée sur un porte-meule (16), la région cylindrique étant radialement décalée par rapport à, et tournant autour de l'axe central de la pièce, **caractérisé en ce que** le calibre (22) est positivement entraîné par une commande autour d'un chemin circulaire de manière à entraîner le calibre à imiter en phase le mouvement complet de la région cylindrique autour de l'axe de la pièce. 5
2. Procédé suivant la revendication 1, comprenant en outre l'étape d'application d'une liaison (36, 40, 48, 50) entre un point d'ancrage et le calibre (22), la liaison s'étendant sur ou sous la région de la pièce en vue de positionner le calibre sur le côté opposé de celle-ci par rapport à la meule, de telle sorte que durant le calibrage, le calibre soit suspendu à la liaison à l'écart de la meule, qu'il soit déplacé par la liaison en contact avec la région à calibrer, et qu'il soit entraîné positivement par l'intermédiaire de la liaison de manière à tourner autour de l'axe de la pièce en phase avec la rotation de la région entourant celui-ci. 10 20 25
3. Procédé suivant la revendication 2, qui comprend l'étape de compensation du poids du calibre et de la liaison, de telle sorte qu'au moins durant le calibrage, le calibre soit uniquement soumis à sa propre inertie. 30
4. Procédé suivant l'une quelconque des revendications 1 à 3, comprenant en outre les étapes d'engagement des côtés opposés de ladite région par une paire de doigts de calibrage (24, 26) du calibre en vue de déterminer la distance entre les doigts et par conséquent le diamètre de la région calibrée; de déplacement des doigts le long d'un premier chemin parallèle au mouvement du porte-meule (10) d'une façon synchronisée et en phase avec celui-ci, de telle sorte qu'un mouvement relatif parallèle audit premier chemin entre ladite région et le calibre soit substantiellement supprimé; et de déplacement du calibre le long d'un deuxième chemin (68) orthogonal au premier chemin et synchronisé avec le mouvement le long du premier chemin, par lequel le calibre décrit un chemin circulaire autour de l'axe de la pièce dont le rayon est similaire à celui du chemin circulaire de la région en cours de meulage et est commandé de manière à être en phase avec la rotation de celle-ci. 35 40 45 50 55
5. Procédé suivant la revendication 4, comprenant l'étape de fixation du calibre (22) à un support (56) monté sur ou entraîné par le porte-meule, de manière à effectuer le mouvement du calibre le long dudit premier chemin, tout en fournissant en entraînement séparé pour effectuer un mouvement du calibre le long dudit deuxième chemin.
6. Procédé suivant la revendication 4, comprenant l'étape de suspension du calibre à l'extrémité d'une structure de poutre oscillante qui est montée de façon pivotante à un support (56) monté sur le porte-meule, d'équilibrage de la structure en vue de compenser le poids du calibre et de la liaison, et d'application d'un entraînement réciproque.
7. Procédé suivant l'une quelconque des revendications 4 à 6, dans lequel le deuxième chemin (68) du calibre est courbe, et est choisi pour être égal à la distance entre l'axe de la meule et l'axe de ladite région lorsque ce dernier se trouve à la position médiane (66) entre les points morts supérieur et inférieur de son mouvement.
8. Procédé suivant la revendication 7, dans lequel le centre de courbure dudit chemin courbe (68) correspond à l'axe (70) de la meule.
9. Procédé suivant l'une quelconque des revendications qui précèdent, dans lequel, dans le cas d'un arrêt d'urgence, le calibre est soit positivement retiré à l'écart de la pièce dans une direction opposée au mouvement du porte-meule, ou est autorisé à effectuer un mouvement rapide et sans entrave par rapport au porte-meule.
10. Dispositif pour déterminer le diamètre d'une région de pièce cylindrique hors d'axe (20) qui décrit un chemin circulaire autour de l'axe de rotation principal de la pièce durant un procédé de meulage, comprenant un calibre (22) ayant deux doigts écartés (24, 26) pour engager ladite région, **caractérisé par** au moins un moyen de commande (64) pour entraîner positivement le calibre (22) autour d'un chemin circulaire, par lequel un point médian entre les doigts écartés traverse le même lieu géométrique que l'axe de la région (20) à meuler, et en phase avec celui-ci, de telle sorte qu'un mouvement relatif entre le calibre et la région soit limité à une non circularité ou à une excentricité de la région par rapport à son propre axe central.
11. Dispositif suivant la revendication 10, comprenant en outre un petit ressort ou un autre dispositif de production de force pour pousser les doigts vers la région, amenant cette dernière à être légèrement serrée entre les doigts.
12. Dispositif suivant la revendication 10, dans lequel un des doigts (24) du calibre (22) est en forme de L et pivote autour de son sommet pour un mouve-

ment d'entrée en contact avec la région de la pièce, de telle sorte qu'une branche (30) du doigt en forme de L entre en contact avec ladite région, entraînant ledit doigt en forme de L à pivoter et à amener l'autre branche du L en contact avec ladite région opposée au point engagé par l'autre doigt (26) du calibre.

13. Dispositif suivant l'une quelconque des revendications 10 à 12, à utiliser sur une meuleuse, comprenant trois entretoises jointes de façon pivotante (40, 48, 50) formant avec un support rigide (56) un parallélogramme articulé, les deux entretoises parallèles (48, 50) étant jointes de façon pivotante à leurs extrémités intérieures au support rigide (56), et ce dernier étant porté par un moyen mobile avec un porte-meule (10) qui incorpore une meule (16), dans lequel le parallélogramme d'entretoises avance et recule en une phase synchronisée avec le porte-meule, et dans lequel l'entretoise extérieure (40) qui est jointe de façon pivotante aux extrémités extérieures des deux entretoises parallèles comprend un montage pour deux pivots écartés, auxquelles des première et deuxième entretoises (36, 44) sont reliées de façon pivotante, dans lequel la première entretoise est jointe de façon pivotante à son extrémité extérieure audit calibre (22), et la deuxième entretoise est reliée à l'extrémité extérieure de la première entretoise (36) à un pivot adjacent au pivot pour ledit calibre, et dans lequel ledit moyen de commande (64) est relié de manière à faire pivoter de façon réciproque le parallélogramme d'entretoises de telle sorte que le calibre décrive un mouvement généralement perpendiculaire au mouvement du porte-meule, par lequel durant la rotation de la région de la pièce (20), les deux mouvements en combinaison entraînent le calibre à décrire substantiellement le même chemin circulaire que la région de la pièce pouvant être engagée par le calibre.
14. Dispositif suivant la revendication 13, dans lequel un desdits pivots écartés (38) auquel ladite première entretoise (36) est attachée, est situé à la verticale au-dessus de l'axe de la région de la pièce (20).
15. Dispositif suivant la revendication 13 ou la revendication 14, dans lequel ladite deuxième entretoise est réglable en longueur, et un moyen de commande (44) est prévu pour réaliser la modification de sa longueur, de telle sorte qu'un mouvement relatif puisse être obtenu entre le calibre (22) et la première entretoise (36), et par conséquent le parallélogramme d'entretoises (40, 48, 50).
16. Dispositif suivant l'une quelconque des revendications 13 à 15, dans lequel ledit support rigide (56) est séparé du porte-meule (10) et un mouvement dudit parallélogramme d'entretoises en harmonie

avec le porte-meule est obtenu par une servocommande séparée sensible à des signaux de commande dérivés des signaux d'alimentation de la roue et/ou à des signaux en provenance d'un codeur associé à un boîtier de commande pour le montage de la pièce.

17. Dispositif suivant l'une quelconque des revendications 13 à 16, dans lequel les deux doigts (24, 26) du calibre (22) engagent légèrement des points diamétralement opposés de la région de la pièce (20), et un autre élément d'engagement de la pièce (30) est situé approximativement à mi-chemin entre les deux doigts et déplacé par rapport à une ligne joignant les deux doigts sur une distance proportionnée au rayon de la région à calibrer, de manière à permettre audit élément d'engager un point sur la surface de la région de la pièce qui est diamétralement opposé au point de contact de la meule avec la région.
18. Dispositif suivant la revendication 17, dans lequel ledit élément (30) est un élément séparé mobile de façon indépendante par rapport au calibre et par conséquent aux deux doigts.
19. Dispositif suivant l'une quelconque des revendications 10 à 18, comprenant en outre un ou plusieurs transducteur(s) associé(s) aux doigts à partir desquels sont dérivés des signaux électriques, correspondant au diamètre moyen déterminé lors de l'engagement initial entre les doigts et la région de la pièce, et correspondant ensuite aux changements de diamètre durant le meulage.
20. Dispositif suivant l'une quelconque des revendications 13 à 19, dans lequel le pivot entre la première entretoise (36) et l'entretoise extérieure (40) définit un axe de pivotement (38) qui est parallèle à l'axe de ladite région de la pièce et reste d'une manière générale verticalement au-dessus de celle-ci comme conséquence de son mouvement avec le porte-meule (10).
21. Dispositif suivant l'une quelconque des revendications 13 à 20, dans lequel la deuxième entretoise comprend au moins en partie un cylindre pneumatique (44), le mouvement du piston dans celui-ci produisant la variation de la longueur totale de l'entretoise, et comprenant en outre un moyen de commande pour fournir de l'air par une canalisation d'air au cylindre afin d'étendre ou de rétracter le cylindre selon ce qui est requis.
22. Dispositif suivant la revendication 21, dans lequel le cylindre (44) est un cylindre à simple action pourvu d'un ressort de rappel, le ressort agissant pour raccourcir la longueur de l'entretoise si la pression

d'air est supprimée.

- 23.** Dispositif suivant l'une quelconque des revendications 13 à 22, comprenant un outre un moyen de production de couple destiné à produire un mouvement tournant autour du pivot d'au moins une des entretoises parallèles (48) dudit parallélogramme, dont la direction et l'ampleur sont choisies de façon à compenser le mouvement tournant opposé autour de ce pivot créé par le poids du calibre et de la structure de support.
- 24.** Dispositif suivant l'une quelconque des revendications 13 à 22, dans lequel l'une des deux entretoises parallèles (48) présente une section étendue (62) au-delà du point de pivotement (58) où elle est attachée au support rigide (56), et le mouvement tournant de la section étendue (62) de l'entretoise est apte à équilibrer d'une manière générale le poids du calibre et de la structure de support, de telle sorte qu'une force réduite soit nécessaire pour faire pivoter de façon réciproque le calibre et la structure.
- 25.** Dispositif suivant l'une quelconque des revendications 10 à 24, dans lequel ledit moyen de commande (64) comprend une servocommande réciproque qui imprime au calibre un mouvement harmonique simple avec une commande de la fréquence et de l'ampleur du mouvement.
- 26.** Dispositif suivant l'une quelconque des revendications 13 à 25, comprenant une commande supplémentaire entre le porte-meule et ledit support rigide pour la structure de support du calibre, qui est également elle-même commandée par un ordinateur, afin de permettre un réglage fin du mouvement d'avance et de recul du calibre dans la direction du mouvement du porte-meule.
- 27.** Dispositif suivant l'une quelconque des revendications 13 à 24, dans lequel la pièce est montée sur un boîtier de commande auquel un codeur est associé en vue de permettre l'obtention d'une information sur la position de rotation instantanée de la pièce, et dans lequel ledit moyen de commande (64) comprend une servocommande associée à la structure de support du calibre et qui agit sur celui-ci de manière à déplacer de façon réciproque les entretoises parallèles, de telle sorte qu'en combinaison avec le mouvement d'avance et de recul du porte-meule, le calibre soit amené à décrire un mouvement circulaire, et dans lequel la servocommande est synchronisée avec la rotation de la pièce en utilisant des signaux de sortie en provenance du codeur du boîtier de commande.
- 28.** Dispositif suivant l'une quelconque des revendications 13 à 27, dans lequel le calibre est attaché à

l'extrémité inférieure de la première entretoise par l'intermédiaire d'une connexion à course perdue (82, 84).

- 29.** Dispositif suivant l'une quelconque des revendications 13 à 28, dans lequel ledit moyen mobile avec un porte-meule et ledit moyen de commande, qui produisent ensemble un mouvement circulaire du calibre, sont constitués par une paire de manivelles rotatives (94, 96) montées pour tourner autour de deux axes verticalement écartés, parallèles à l'axe principal de la pièce (W), et joints par une liaison rigide (98) qui s'étend vers le bas en dessous de la manivelle inférieure de la paire où elle est fixée au calibre (22"), dans lequel le rayon des manivelles et la vitesse de rotation sont sélectionnés de manière à correspondre au rayon du mouvement circulaire de la région de la pièce, et à la vitesse de rotation de la région autour de l'axe principal de la pièce (W), de telle sorte que le calibre décrive le même chemin circulaire en phase avec le mouvement circulaire de la région de la pièce.

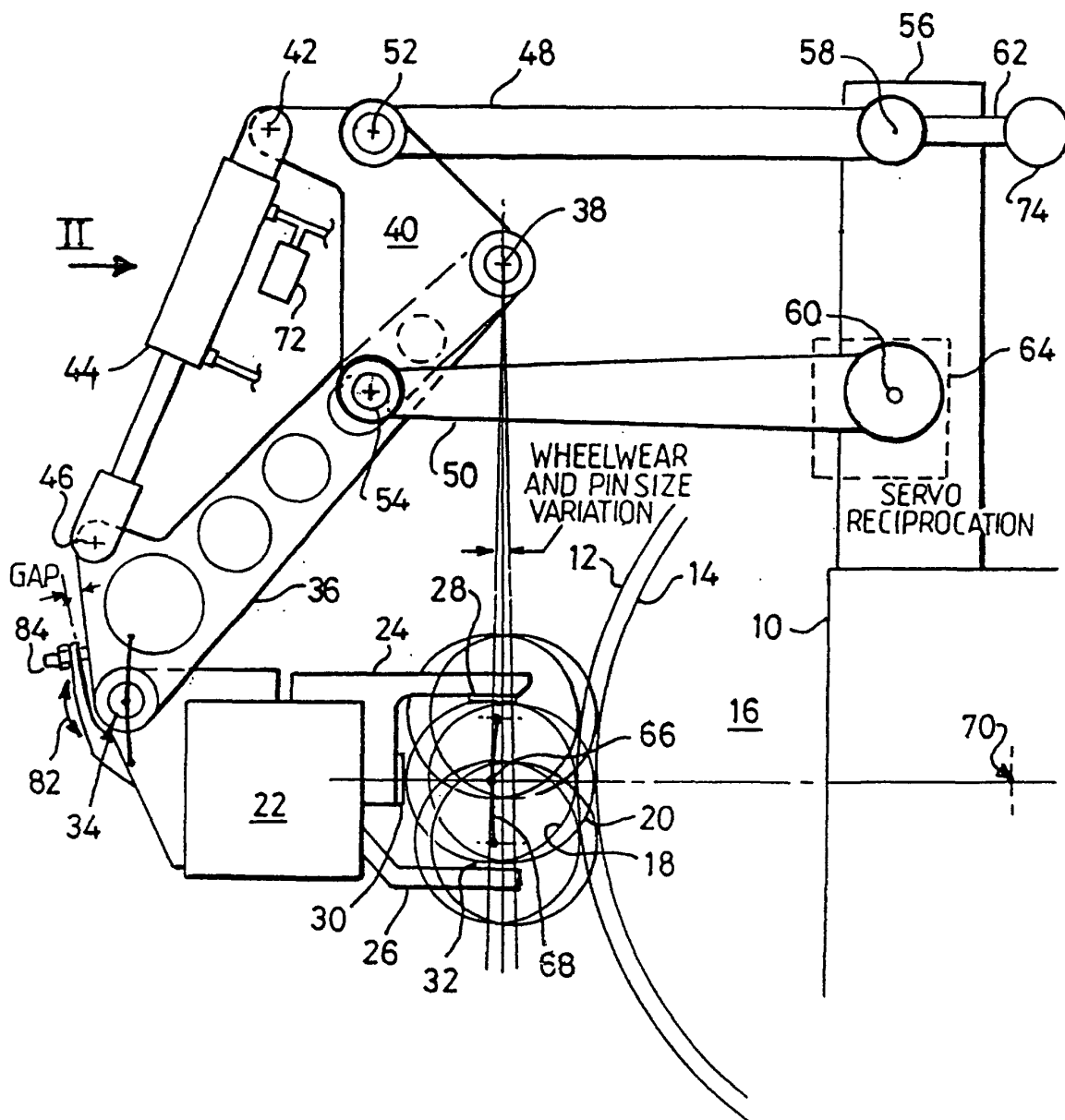
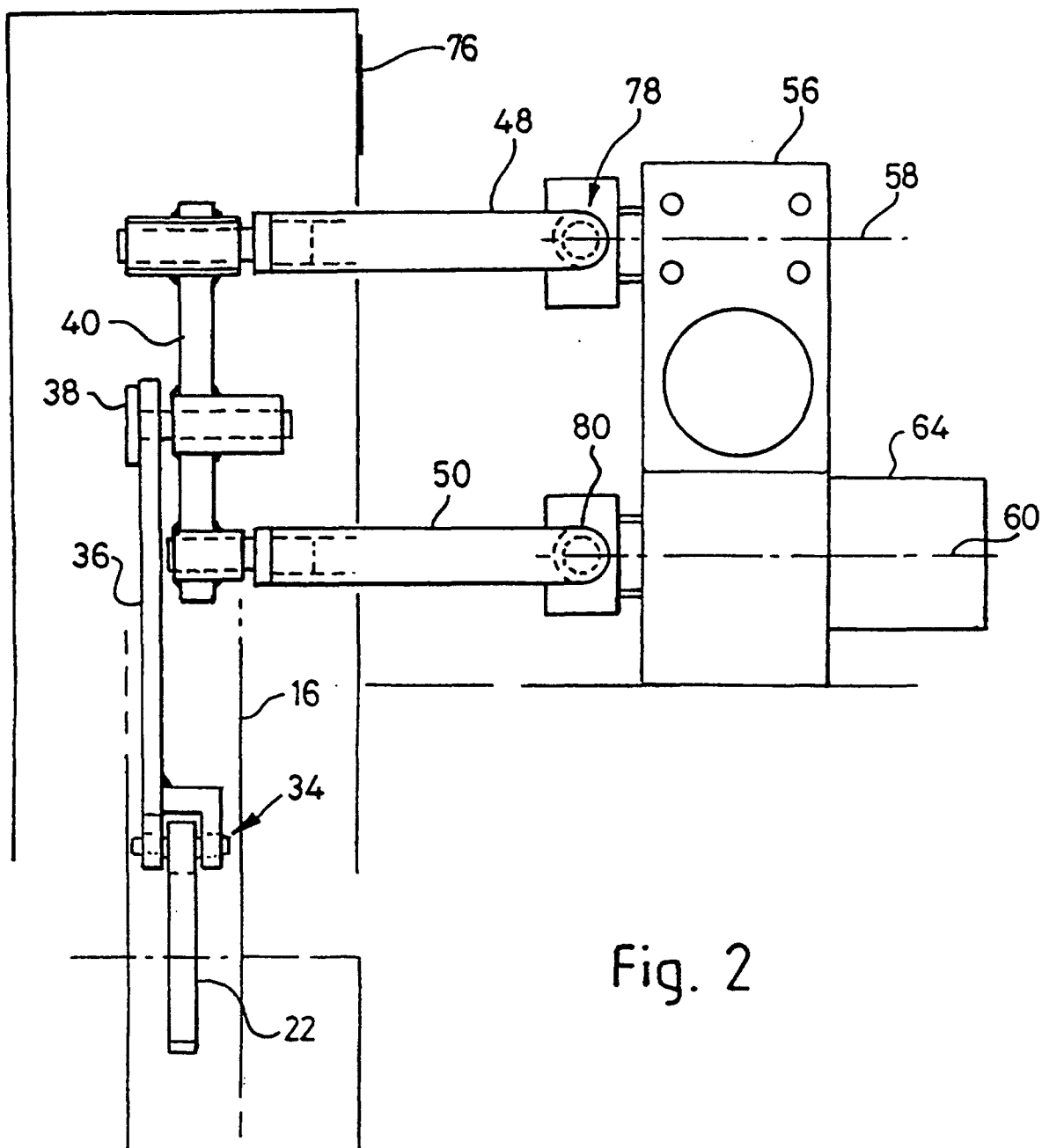


Fig. 1



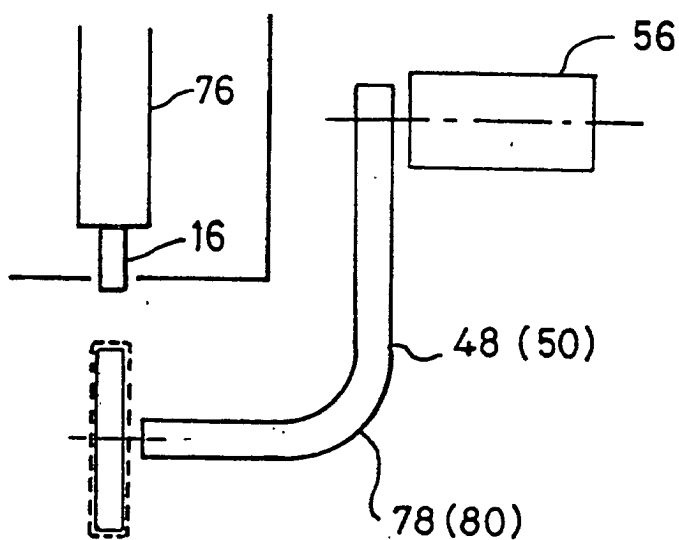


Fig. 3

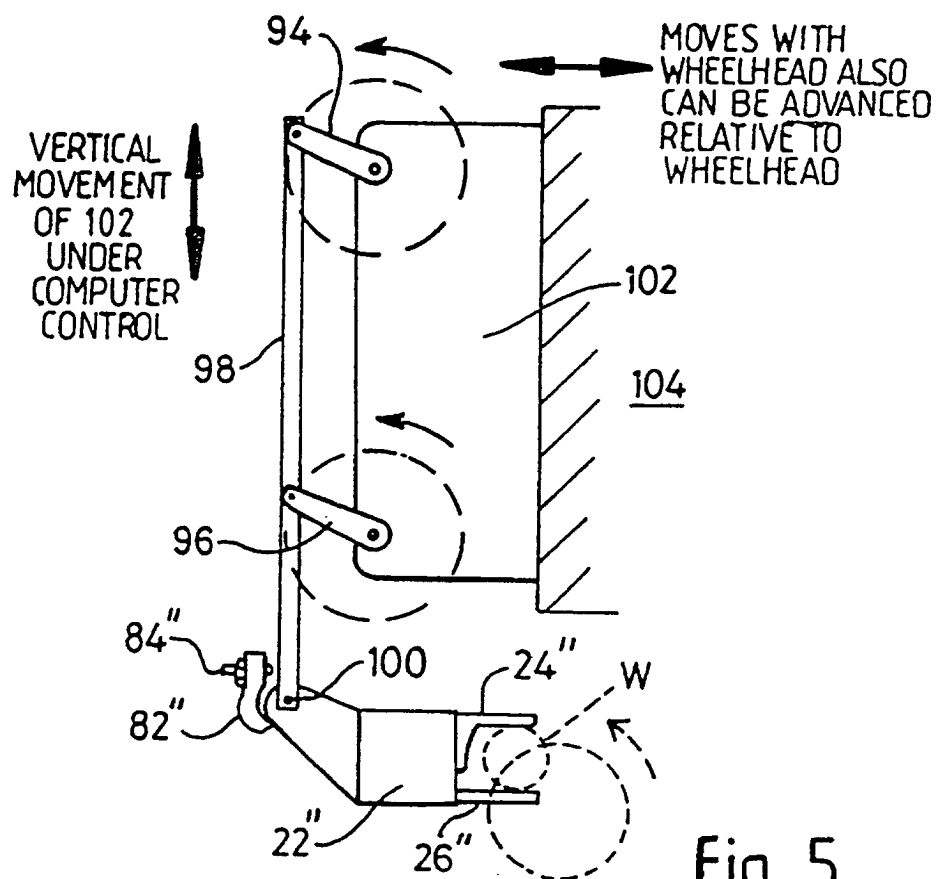


Fig. 5

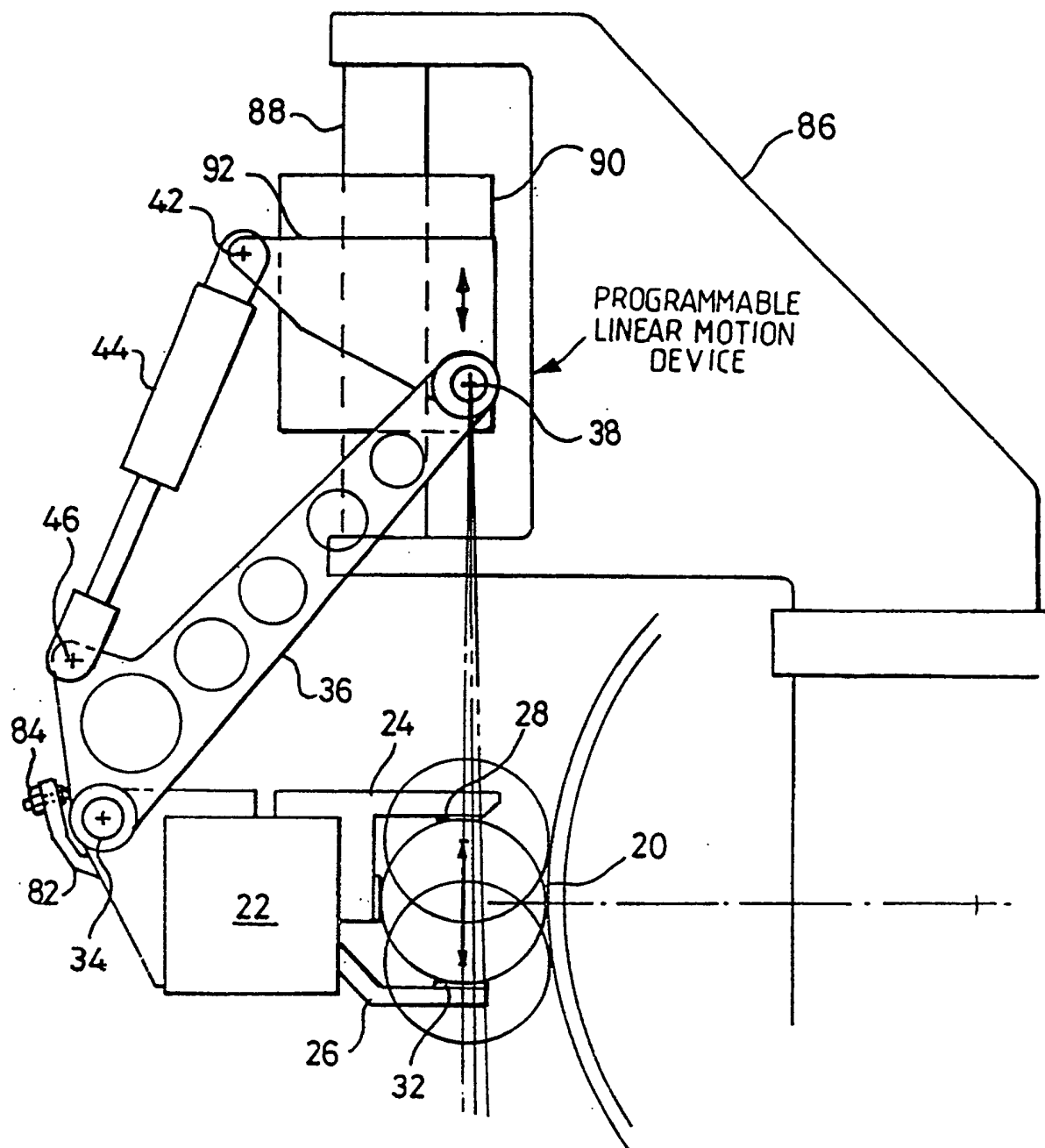


Fig. 4