



(11) **EP 1 635 989 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:  
**24.10.2007 Bulletin 2007/43**

(51) Int Cl.:  
**B24B 5/42 (2006.01) B24B 27/00 (2006.01)**

(21) Application number: **05740437.8**

(86) International application number:  
**PCT/GB2005/001727**

(22) Date of filing: **06.05.2005**

(87) International publication number:  
**WO 2005/110676 (24.11.2005 Gazette 2005/47)**

(54) **IMPROVEMENTS IN AND RELATING TO THE GRINDING OF CYLINDRICAL SURFACES AND ADJOINING SIDE-WALLS**

VERBESSERUNGEN BETREFFEND DAS SCHLEIFEN VON ZYLINDRISCHEN FLÄCHEN UND DARAN ANGRENZENDEN SEITENFLÄCHEN

AMELIORATIONS RELATIVES AU MEULAGE DE SURFACES CYLINDRIQUES ET DE PAROIS LATERALES ADJACENTES

(84) Designated Contracting States:  
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR  
HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR**

(30) Priority: **15.05.2004 GB 0410944**  
**21.06.2004 GB 0413783**

(43) Date of publication of application:  
**22.03.2006 Bulletin 2006/12**

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## Description

### Field of invention

**[0001]** This invention concerns grinding methods and grinding machines particularly for grinding the main cylindrical bearing support surfaces and their adjacent sidewalls and the off-axis cylindrical crankpins and their adjacent sidewalls, of a crankshaft.

### Background

**[0002]** EP-A-990483 discloses a grinding machine for grinding a crankshaft using two grinding wheels. Pin portions of the crankshaft are ground by moving the wheels along axes perpendicular to the rotational axis of the crankshaft.

**[0003]** A plunge grinding method is described in US patent 4,603,514 (Toyota). This method involves a sequence of plunge grinds in which during at least some of the plunge grinds the relative movement between grinding wheel and workpiece is such that if the workpiece is considered to be stationary the wheel will be seen to move along a trajectory that is at an acute angle to the axis of the cylindrical surface it is to grind, and during grinding the wheel removes metal from both the cylindrical surface and an adjoining sidewall.

### Summary of the invention

**[0004]** The present invention is directed at a method of operating a grinding machine including a grinding wheel to grind a cylindrical surface on a workpiece, the cylindrical surface being bounded at one or both ends with a radial flange or sidewall which also has to be ground to size. According to the invention, the method comprises the steps of:-

- (1) carrying out an angled plunge grind at an angle of wheel advance selected so that the sidewall grind will be completed ahead of the cylindrical grind,
- (2) after the sidewall grind has been completed, standing off the wheel from the sidewall, so that only the cylindrical circumferential surface (the face) of the wheel will make grinding engagement with the workpiece at least at the start of the final part of the grind, and
- (3) plunge grinding the cylindrical surface to achieve the final diameter required of the cylindrical surface.

**[0005]** The stand-off may be achieved by axially displacing the wheel relative to the workpiece or the workpiece relative to the grinding wheel by a small distance.

**[0006]** During the final part of the plunge grind the relative axial movement may be stopped and the movement reversed for a small distance to create the stand-off so that thereafter the trajectory of the wheel is normal to the cylindrical surface to be ground. Alternatively in some

circumstances after creating the stand-off the wheel may be advanced along an angled path similar to that employed during the previous part of the grind, the stand-off preventing contact with, and metal removal from, the sidewall during the final angled approach of the wheel to complete the grind.

**[0007]** Preferably during the final part of the plunge the workspeed is reduced from the speed at which it is rotated during the previous part of the plunge to assist in achieving a desired grinding quality of the cylindrical region.

**[0008]** Preferably during the final part of the plunge the coolant flow rate is reduced from that which is employed during the previous part of the plunge, so as to achieve a desired grind quality of the cylindrical region.

**[0009]** The method is applicable to grinding the cylindrical crank-pins or the main bearing support surfaces of a crankshaft, but can be employed when grinding any cylindrical surface bounded at one or both ends with a radial flange which also has to be ground to size.

**[0010]** In a method embodying the invention a diameter and two sidewalls are ground using a succession of two angled plunge grinds albeit with the side face of the grinding wheel stood off from the sidewall of the workpiece during a final part of each plunge grind. During each angled plunge grind, feed rate, dwells, workspeed, coolant pressure and flow rate are controlled in relation to end-points of the grind, so that a sidewall at one end of the cylindrical surface and the adjacent part of the latter are ground to size in the manner hereinbefore described.

**[0011]** After grinding the sidewall and diameter by the first plunge grind at one end, the wheel is retracted and if necessary indexed laterally before a second angled plunge grind is performed this time moving the wheel along a trajectory towards the sidewall at the other end of the cylindrical surface, thereby to grind the sidewall and diameter at the other end of the cylindrical surface.

**[0012]** Preferably the lateral indexing is not more than  $\frac{2}{3}$  of the wheel width so as to ensure overlap on the diameter between plunges.

**[0013]** If the wheel width is insufficient for the whole length of the cylindrical surface to be ground to diameter by the two angled plunge grinds, one or more perpendicular plunge grinds may be performed between the first and second angled plunge grinds or after the second angled plunge grind.

**[0014]** Preferably the process employs a dressed profiled wheel.

**[0015]** Information from the dressing of the wheel and the position of the wheel faces allows the sidewalls and diameters to be ground accurately.

**[0016]** Since the side faces are each employed in turn the wheel can have an equal depth of CBN grit on each of the two side faces, and by selecting an appropriate depth of CBN grit around the cylindrical face of the wheel, the wheel should wear uniformly in use so that all of the CBN grit around the wheel should be utilised before the wheel has to be replaced.

**[0017]** If the quantity of metal to be removed on the

diameter is approximately 50% of that to be removed from the sidewalls, then using a 35.00mm wide CBN wheel, the thickness of the CBN layers can be as follows:-

- CBN layer on (cylindrical) face of the wheel = 5.0mm.
- CBN layer on left side face of the wheel = 5.0mm.
- CBN layer on right side face of the wheel = 5.0mm.

**[0018]** This gives a total dressable width on the wheel of 10.0mm.

**[0019]** The invention is also directed at a grinding machine and programmable computer based control system therefor, programmed to grind a cylindrical region bounded by at least one radial sidewall on a workpiece by way of a series of plunge grinds. According to the invention, the control system is programmed to control a grinding wheel of the machine so as to grind the or each sidewall to size before the adjoining cylindrical surface is ground to the correct diameter, and to cause the wheel to stand-off from the ground to size sidewall at least at the start of a final plunge grind of the diameter.

**[0020]** A two-wheel grinding machine may be employed, each wheel being controlled to perform an angled grind with lateral stand-off thereafter, prior to the final part of each grind provided the two wheels are independently controllable along the X and Z axes of the machine.

**[0021]** A method embodying the invention and part of apparatus for performing the method is shown in the accompanying Figs 1-14.

**[0022]** A typical computer controlled grinding machine is shown in Fig 15, a diagrammatic illustration of the external parts of the grinding machine is shown in Fig 16 and the computer program steps involved in operating the machine to perform the sidewall grind in accordance with the diagonal grinding proposed by the invention, is shown in Fig 17.

**[0023]** The method will first be described with reference to Figs 1-14.

**[0024]** In Fig 1 the wheelhead is moved axially relative to the crankshaft 4 in the direction marked "A" so as to be positioned adjacent the region to be ground for first plunge grind. This is referred to as the lateral start position of the wheel 2.

**[0025]** In Fig 2 the wheel 2 is shown after a rapid plunge move in the direction marked "B" to an end point in which the wheel is at an equal distance from the sidewall 6 and cylindrical region 8 to be ground.

**[0026]** In Fig 3 the wheel is shown during an angled plunge to the right in the direction marked "C" using programmable feeds in the directions of the RH sidewall 6 and the cylindrical region 8, to programmable end points. Ideal angle of feed is 45° with the sidewall end point 6' being reached before that of the central region diameter 8' by a distance "x" of approximately 0.010mm. Other functions controlled during the plunge by means of staggered control end points are dwells, multi-stage feedrates, coolant pressure control and workspeeds, to gain a desired grind quality. The part rotation speed is typically

80RPM (journal) or 40RPM (pin).

**[0027]** In Fig 4 the wheel is shown in the stand-off position (after movement in the direction marked "D") required before the remainder of the right hand plunge grind is performed. The stand-off positions the wheel a distance of "y" 0.050mm clear of the sidewall. The work-speed and coolant flow rate are reduced and the wheel continues to advance perpendicularly to the axis of the cylindrical region. Typically the workpiece is rotated at 20RPM. By arresting the axial displacement of the workpiece (employed during the previous part of the grind to achieve the 45° effective angle of feed) the stand-off is preserved during the final part of the plunge grind.

**[0028]** In Fig 5 the wheel is shown at the end point of the final part of the plunge after movement in the direction marked "E", during which the sequence continues to use the staggered control end points, controlling dwells, multistage feedrates, coolant pressure control and workspeeds, to ensure the desired grind quality for the cylindrical surface.

**[0029]** In Fig 6 the wheel is shown retracted in direction "F" clear of the workpiece to a programmable safe position from the wheelhead to allow lateral indexing of the wheelhead towards the LH end of the region being ground.

**[0030]** In Fig 7 the wheel is shown after lateral indexing in direction "G" to an initial position for the second angled plunge grind.

**[0031]** In Fig 8 the wheel is shown after a rapid plunge movement in direction "H" to the end point from which the LH angled plunge grind is to begin. This corresponds to the start position of Fig 2 for the RH angled plunge.

**[0032]** In Fig 9 the wheel is shown during the angled LH plunge grind during which programmable feeds in the directions of the LH sidewall and central region diameter are used, to move the wheel in direction "I" to programmable end points. Again the ideal angle of feed is 45°, with the LH sidewall end point being reached before that of the central region diameter by approximately 0.010mm. As with the RH angled plunge other functions controlled during the plunge by means of staggered control end points are dwells, multi-stage feedrates, coolant pressure control and workspeeds, to gain the desired grind quality. Typically the part rotation speed is 80RPM (journal) or 40RPM (pin).

**[0033]** Fig 10 shows the wheel in its second stand-off position - in which the wheel is once again stood off in direction "J" by 0.050mm (distance "z") this time from the LH sidewall, and the workspeed and coolant flow rate are reduced. The speed of rotation may be reduced to 20RPM, typically. If the axial movement of the workpiece is arrested during the final part of the grind, the grinding trajectory will be perpendicular to the axis of the cylindrical region, instead of at 45°.

**[0034]** In Fig 11 the wheel is shown at the end point of the final part of the plunge in direction "K", during which the sequence continues to use the staggered control end points, controlling dwells, multi-stage feedrates, coolant

pressure control and workspeeds, to ensure the desired grind quality for the cylindrical surface.

**[0035]** In Fig 12 the wheel is shown retracted clear of the workpiece in direction "L" to a programmable safe position ready for subsequent lateral indexing of the wheelhead relative to that region of the workpiece if a further plunge grind is required, (typically without simultaneous axial movement of the workpiece) should the width of the wheel be insufficient for the whole of the axial length of the cylindrical region to have been ground to final diameter.

**[0036]** In Fig 13 the wheel 2 is shown further retracted so that the wheelhead can index to the next part of the crankshaft 4 which is to be ground, and the multiple plunge grind sequence is repeated from Fig 1 above.

**[0037]** Fig 14 shows a crankshaft workpiece 4 mounted between headstock 10 and tailstock 12 with the wheelhead 14 ready to advance to the first grinding position, but parked in a position clear of the workpiece to allow the latter to be demounted or mounted.

**[0038]** Fig 15 shows a grinding machine 68. The machine shown includes two grinding wheels 70,72 driven by motors 74,76 and mounted on wheelheads 78,80 for separate and simultaneous movement towards and away from a workpiece 82 along linear tracks 84,86 under the control of wheelfeed drive motors 88,90. The workpiece is mounted between centres in a tailstock 92 and a headstock 94 which also houses a motor (not shown) for rotating the workpiece 82 via a chuck 96. The workpiece shown is a crankshaft of an internal combustion engine and includes offset crankpins such 98 which are to be ground to size, each of which constitutes a cylindrical workpiece for grinding.

**[0039]** Although two grinding wheels are shown on the machine of Fig 15 it is to be understood that one of the wheels, wheelheads and drive motors can be omitted so that the machine contains only one grinding wheel (e.g. 70) as shown in Figs 1-14.

**[0040]** A computer 100 running a suitable programme controls the operation of the machine and inter alia moves the wheelhead 78 (or both wheelheads 78,80) towards and away from the workpiece 82 as the workpiece rotates, so as to maintain contact between the wheel and the crankpin being ground, as the latter rotates circularly around the axis of the workpiece centres.

**[0041]** A gauge, not shown, may be carried by the wheelhead assembly for in-process gauging the diameter of the crankpin as it is ground.

**[0042]** At 102 is mounted a hydraulically or pneumatically operated worksteady having a base 104 and movable cantilever arm 106 adapted at the right hand end as shown to engage a cylindrical journal bearing region of the crankshaft workpiece 82. Controlling signals for advancing and retracting 106 are derived from the computer 100.

**[0043]** Wheel diameter sensing gauges may be included, signals from which are supplied back to the computer 100.

**[0044]** In accordance with the present invention the wheelhead 78 is movable along an axis parallel to the workpiece axis (the Z axis) by a further drive.

**[0045]** In Fig 16 the essential parts of the machine are shown namely a wheelhead 200 having a wheel drive motor 202, a Z-axis feed drive motor 204 and an X-axis feed drive motor 206. The X and Z axes are denoted by labelled arrows. A grinding wheel 208 is mounted to one side of the wheelhead 200 and movement of the wheelhead is controlled by signals from a computer based control system 210.

**[0046]** A workpiece 212 is shown mounted between headstock 214 and tailstock 216. The former includes a C-axis drive motor (not shown) for rotating the workpiece about its lengthwise axis. The workpiece includes radial flanges at 218, 220 between a cylindrical region 222 and the purpose of the grind is to finish grind the opposed sidewalls denoted by 224, 226 and the diameter of the cylindrical region 222.

**[0047]** In accordance with the invention the wheelhead is moved relative to the workpiece so that one sidewall of the grinding wheel is brought into grinding contact with one of the two sidewalls (for example 224) of the workpiece, the feed movement of the wheelhead being controlled along both X and Z axes, so that the wheel and wheelhead describe a trajectory which makes an acute angle with the workpiece axis - typically 45°, until the sidewall grind is complete, after which the wheel is stood off from the sidewall 224 and the wheelhead is advanced so as to finish the grind the diameter of region 222, whilst maintaining the stand off between the sidewall of wheel and the sidewall of workpiece 224.

**[0048]** The other workpiece sidewall 226 is then ground using the other sidewall of the grinding wheel, and the remainder of the cylindrical region 222 is ground, whilst the wheel is stood off from the second workpiece sidewall 226.

**[0049]** Fig 17 shows the steps required to be performed by the computer 210 in response to feedback from gauges and or X and Z axis position signals.

**[0050]** Grinding is initiated by step 228 which causes wheel feed 206 to move the wheelhead 200 parallel to the X-axis. The X-feed 206 is controlled so that a specific diameter of the region 222 will be ground.

**[0051]** The X-feed is monitored and when the wheel has reached the sidewall grind start position (well before the wheel has reached the region 222) step 230 produces a YES signal to initiate a sidewall grind.

**[0052]** Here it will be assumed that the first sidewall to be ground is 226 of Fig 16.

**[0053]** Step 282 of the programme causes Z-axis movement towards the chosen sidewall (226 in the example under consideration) which is simultaneous with the X-axis movement initiated by step 228.

**[0054]** Step 232 provides two outputs one to a Z-axis drive controlling step 234 and one to a monitoring logic step 236 which determines whether the X-axis feed has achieved the desired diameter of the region 222.

**[0055]** The Z-axis movement is monitored by step 238 which produces a YES signal when the combined X and Z axes movement has resulted in the sidewall 226 having been ground to size (measured in the Z direction).

**[0056]** A YES signal from step 238 triggers step 240 to instigate a reverse Z-axis motion to back off the sidewall of the wheel 208 from contact with the sidewall 216, now ground to size. An output signal from 240 indicates back off is completed.

**[0057]** A logic stage 242 provides a YES signal if the output signal from 240 indicates back off is complete and the X-axis movement has achieved the desired position in region 222.

**[0058]** A similar logic stage 244 provides a YES signal if the sidewall cycle including back-off is complete when the monitoring step 235 confirms that the region 222 has been ground to size.

**[0059]** When both 242 and 244 provide a YES signal, step 246 reverses the X-feed drive 206 to retract the wheel.

**[0060]** Grinding of the other sidewall 224 is achieved by reversing the Z-axis commands to the Z-axis drive 204 whilst performing similar X-axis movements in response to signals from the computer 210.

## Claims

1. A method of operating a grinding machine (68) including a grinding wheel (2) to grind a cylindrical surface (8) on a workpiece (4), the cylindrical surface being bounded at one or both ends with a radial flange or sidewall which also has to be ground to size, **characterised in that** the method comprises the steps of:-

- (1) carrying out an angled plunge grind (C, I) at an angle of wheel advance selected so that the sidewall grind will be completed ahead of the cylindrical grind,
- (2) after the sidewall grind has been completed, standing off (D, J) the wheel from the sidewall, so that only the cylindrical circumferential surface of the wheel will make grinding engagement with the workpiece at least at the start of the final part of the grind, and
- (3) plunge grinding (E, K) the cylindrical surface of the workpiece to achieve the final diameter required of the cylindrical surface.

2. A method as claimed in claim 1 wherein the stand-off is achieved by axially displacing the wheel (2) relative to the workpiece (4) in a direction parallel to the longitudinal axis of the cylindrical surface.
3. A method as claimed in claim 1 wherein the stand-off is achieved by axially displacing the workpiece (4) relative to the grinding wheel (2) in a direction

parallel to the longitudinal axis of the cylindrical surface.

4. A method as claimed in claim 2 or claim 3 wherein the relative axial movement is stopped, the movement is reversed for a small distance to create the stand-off and thereafter the trajectory of the wheel is normal to the cylindrical surface to be ground.
5. A method as claimed in any of claims 1 to 3 wherein during its final movement to complete the grind after creating the stand off, the wheel (2) is advanced along an angled path similar to that employed during the previous part of the grind, the stand-off being such as to prevent contact with the sidewall during the wheel movement after the stand-off, and thereby preventing further metal removal from the sidewall during the final angled approach of the grinding wheel.
6. A method as claimed in any of claims 1 to 5 wherein during the final part of the plunge the workspeed is reduced from the speed at which it is rotated during the previous part of the plunge prior to the stand-off.
7. A method as claimed in any of claims 1 to 6 wherein during the final part of the plunge the coolant flow rate is reduced from that which is employed during the previous part of the plunge prior to the stand-off.
8. A method as claimed in any of claims 1 to 7 wherein the workpiece (4) is an internal combustion engine crankshaft.
9. A method as claimed in claim 8 wherein the cylindrical and sidewall regions comprise the support surfaces for a main bearing of the crankshaft.
10. A method as claimed in claim 8 wherein the cylindrical and sidewall regions comprise those associated with a crankpin of the crankshaft.
11. A method as claimed in any preceding claim wherein the cylindrical surface (8) is bounded at both ends with a radial flange or sidewall, and the cylindrical surface and two sidewalls are ground using a succession of two angled plunge grinds (C, I) wherein the side face of the grinding wheel is stood off from a sidewall of the workpiece during a final part of each plunge grind.
12. A method as claimed in claim 11 wherein during a first angled plunge grind (C), feed rate, dwells, workspeed, coolant pressure and flow rate are controlled in relation to end-points of the grind, so that the sidewall at one end of the cylindrical surface and the adjacent part of the latter are ground to size.

13. A method as claimed in claim 12 wherein after grinding the sidewall and diameter by the first plunge grind at one end of the cylindrical surface, the wheel is retracted, and a second angled plunge grind (I) is then performed this time moving the wheel along a trajectory towards the sidewall at the other end of the cylindrical surface, thereby to grind the sidewall and diameter at the other end of the cylindrical surface. 5
14. A method as claimed in claim 13 wherein the wheel is indexed laterally prior to the second angled plunge grind (I) being performed. 10
15. A method as claimed in claim 14 wherein the lateral indexing is not more than 2/3 of the wheel width so as to ensure overlap on the diameter between plunges. 15
16. A method as claimed in claim 14 wherein the wheel width is insufficient for the whole length of the cylindrical surface to be ground to diameter by the two angled plunge grinds (C, I), and at least one perpendicular plunge grind (E) is performed to grind the central region of the cylindrical surface (8). 20
17. A method as claimed in claim 16 wherein the at least one perpendicular plunge grind (E) is performed between the first and second angled plunge grinds (C, I). 25
18. A method as claimed in claim 16 wherein the at least one perpendicular plunge grind (K) is performed after the second angled plunge grind (I). 30
19. A method as claimed in any of claims 1 to 18 wherein a dressed profiled wheel is employed. 35
20. A method as claimed in claim 19 further comprising the step of delivering information from the dressing of the wheel and the position of the wheel faces to a control system (100) of the grinding machine (68), the control system controlling the grinding of the sidewalls and diameters therefrom. 40
21. A method as claimed in any of claims 1 to 20 wherein the wheel has an equal depth of grit on each of the two side faces, and an appropriate depth of grit is selected for the cylindrical face of the wheel, so that if the wheel wears uniformly in use, substantially all of the grit around the side and cylindrical faces of the wheel will be utilised before the wheel has to be replaced. 45
22. A method as claimed in claim 21 wherein the wheel grit is CBN. 50
23. A grinding machine (68) and programmable compu-

ter based control system (100, 210) therefor, programmed to grind a cylindrical surface (222) bounded by at least one radial sidewall (224, 226) on a workpiece (212) by way of a series of plunge grinds, **characterised in that** the control system is programmed to control a grinding wheel (208) of the machine so as to grind the or each sidewall to size before the adjoining cylindrical surface is ground to the correct diameter, and to cause the wheel to stand-off from the ground to size sidewall at least at the start of a final plunge grind of the diameter.

24. A grinding machine and control system as claimed in claim 23, the grinding machine including two grinding wheels which are independently controllable along the X and Z axes of the machine, wherein each wheel is controlled to perform an angled grind with lateral stand-off thereafter, prior to the final part of each grind.

#### Patentansprüche

1. Verfahren für den Betrieb einer Schleifmaschine (68) einschließlich- einer Schleifscheibe (2) zum Schleifen einer zylindrischen Fläche (8) an einem Werkstück (4), wobei die zylindrische Fläche an einer oder beiden Seiten durch einen radialen Flansch oder eine Seitenwand begrenzt ist, die ebenfalls in die gewünschte Abmessung geschliffen werden muss, **dadurch gekennzeichnet, dass** das Verfahren folgende Schritte umfasst:
  - (1) Ausführen eines schräg geführten Einstechschliffs (C, I) mit einem Winkel des Schleifscheibenvorschubs, der so gewählt ist, dass das Schleifen der Seitenwand vor dem zylindrischen Schleifen vollendet ist,
  - (2) nach Vollenden des Seitenwand-Schleifens, Freistellen (D, J) der Schleifscheibe von der Seitenwand, so dass nur die zylindrische umlaufende Fläche der Schleifscheibe in Schleißkontakt mit dem Werkstück kommt, zumindest bei Beginn des letzten Teils des Schleifens, und
  - (3) Einstechschleifen (E, K) der zylindrischen Fläche des Werkstücks, um den Enddurchmesser zu erreichen, den die zylindrische Fläche haben soll.
2. Verfahren nach Anspruch 1, bei dem das Freistehen erreicht wird, indem die Scheibe (2) bezogen auf das Werkstück (4) axial in einer Richtung verschoben wird, die zur Längsachse der zylindrischen Fläche parallel ist.
3. Verfahren nach Anspruch 1, bei dem das Freistehen erreicht wird, indem das Werkstück (4) bezogen auf die Schleifscheibe (2) axial in einer Richtung ver-

schoben wird, die zur Längsachse der zylindrischen Fläche parallel ist.

4. Verfahren nach Anspruch 2 oder 3, bei dem die relative axiale Verschiebung gestoppt wird und die Bewegung für eine kleine Strecke umgekehrt wird, um das Freistehen zu bewirken, und danach verläuft die Bahn der Schleifscheibe senkrecht zu der zu schleifenden zylindrischen Fläche. 5
5. Verfahren nach einem der Ansprüche 1 bis 3, bei dem die Schleifscheibe (2), während ihrer Endbewegung zur Vollendung des Schliffs nach Herstellen des Freistehens, entlang einer schrägen Bahn vorwärts bewegt wird, ähnlich derjenigen, die während des vorhergehenden Teils des Schleifvorgangs verfolgt wurde, wobei das Freistehen derart ist, dass ein Kontakt mit der Seitenwand während der Bewegung der Schleifscheibe nach dem Freistellen verhindert wird und **dadurch** ein weiteres Entfernen von Metall von der Seitenwand während der letzten schräg geführten Annäherung der Schleifscheibe verhindert wird. 10
6. Verfahren nach einem der Ansprüche 1 bis 5, bei dem während des letzten Teils des Einstechschleifens die Arbeitsgeschwindigkeit verringert wird, bezogen auf die Rotations-Geschwindigkeit während des vorhergehenden Teils des Einstechschleifens vor dem Freistellen. 15
7. Verfahren nach einem der Ansprüche 1 bis 6, bei dem während des letzten Teils des Einstechschleifens die Durchflussmenge des Kühlmittels reduziert wird, bezogen auf diejenige, die vor dem Freistellen während des vorhergehenden Teils des Einstechschleifens eingesetzt wurde. 20
8. Verfahren nach einem der Ansprüche 1 bis 7, wobei das Werkstück (4) eine Kurbelwelle eines Verbrennungsmotors ist. 25
9. Verfahren nach Anspruch 8, wobei die zylindrischen Bereiche und die Seitenwand-Bereiche die Auflageflächen für ein Hauptlager der Kurbelwelle umfassen. 30
10. Verfahren nach Anspruch 8, wobei die zylindrischen Bereiche und die Seitenwand-Bereiche diejenigen Bereiche umfassen, die mit einem Kurbelwellenzapfen der Kurbelwelle verbunden sind. 35
11. Verfahren nach einem der vorhergehenden Ansprüche, wobei die zylindrische Fläche (8) an beiden Seiten von einem radialen Flansch oder einer Seitenwand begrenzt ist, und die zylindrische Fläche und zwei Seitenwände werden in zwei aufeinanderfolgenden schräg geführten Einstechschliffen (C, I) ge-

schliffen, wobei die Seitenfläche der Schleifscheibe während eines abschließenden Teils jedes Einstechschleifens von einer Seitenwand des Werkstücks freigestellt ist.

12. Verfahren nach Anspruch 11, bei dem während eines ersten schräg geführten Einstechschleifens (C) die Vorschubgeschwindigkeit, Verweildauer, Arbeitsgeschwindigkeit, Druck und Fließgeschwindigkeit des Kühlmittels gesteuert werden in Bezug auf Endpunkte des Schleifens, so dass die Seitenwand an einer Seite der zylindrischen Fläche und der benachbarte Teil der letzteren in die gewünschte Abmessung geschliffen werden. 40
13. Verfahren nach Anspruch 12, bei dem nach dem Schleifen der Seitenwand und des Durchmessers durch den ersten Einstechschliff an einer Seite der zylindrischen Fläche die Schleifscheibe zurückgezogen wird, und dann ein zweiter schräg geführter Einstechschliff (I) ausgeführt wird, wobei dieses Mal die Schleifscheibe entlang einer Bahn zur Seitenwand an der anderen Seite der zylindrischen Fläche bewegt wird, um **dadurch** die Seitenwand und den Durchmesser an der anderen Seite der zylindrischen Fläche zu schleifen. 45
14. Verfahren nach Anspruch 13, wobei die Schleifscheibe in Querrichtung verstellt wird, bevor der zweite schräge Einstechschliff (I) ausgeführt wird. 50
15. Verfahren nach Anspruch 14, wobei die Verstellung in Querrichtung nicht mehr als 2/3 der Schleifscheibenbreite beträgt, um so die Überlappung auf dem Durchmesser zwischen den Einstechschliffen zu gewährleisten. 55
16. Verfahren nach Anspruch 14, wobei die Schleifscheibenbreite nicht ausreichend ist für die gesamte Breite der zylindrischen Fläche, die durch die zwei schräg geführten Einstechschliffe (C, I) auf den gewünschten Durchmesser geschliffen werden soll, und wobei mindestens ein senkrechter Einstechschliff (E) ausgeführt wird, um den zentralen Bereich der zylindrischen Fläche (8) zu schleifen.
17. Verfahren nach Anspruch 16, bei dem mindestens ein senkrechter Einstechschliff (E) zwischen dem ersten und dem zweiten schräg geführten Einstechschliff (C, I) ausgeführt wird.
18. Verfahren nach Anspruch 16, bei dem mindestens ein senkrechter Einstechschliff (K) nach dem zweiten schräg geführten Einstechschliff (I) ausgeführt wird.
19. Verfahren nach einem der Ansprüche 1 bis 18, bei dem eine abgerichtete Profilschleifscheibe verwen-

det wird.

20. Verfahren nach Anspruch 19, das außerdem den Schritt umfasst, Daten bezüglich des Abrichtens der Schleifscheibe und der Position der Schleifscheiben-Arbeitsflächen an ein Steuersystem (100) der Schleifmaschine (68) zu liefern, wobei das Steuersystem das Schleifen der Seitenwände und deren Durchmesser steuert. 5
21. Verfahren nach einem der Ansprüche 1 bis 20, wobei die Schleifscheibe die gleiche Schleifmaterial-Stärke auf jeder der zwei Seitenflächen hat, und eine geeignete Schleifmaterial-Stärke für die zylindrische Fläche der Schleifscheibe gewählt wird, so dass, wenn sich die Schleifscheibe bei Gebrauch gleichmäßig abnutzt, im wesentlichen das gesamte Schleifmaterial auf den Seitenflächen- und der zylindrischen Fläche verbraucht ist, bevor die Schleifscheibe ausgetauscht werden muss. 10
22. Verfahren nach Anspruch 21, bei dem das Schleifmaterial CBN ist. 15
23. Schleifmaschine (68) und rechnergestütztes programmierbares Steuersystem (100, 210) hierfür, das programmiert ist, um eine zylindrische Fläche (222), die durch mindestens eine radiale Seitenwand (224, 226) begrenzt ist, eines Werkstücks (212) durch eine Reihe von Einstechschliffen zu schleifen, **dadurch gekennzeichnet, dass** das Steuersystem so programmiert ist, dass es eine Schleifscheibe (208) der Maschine so steuert, dass die oder jede Seitenwand in die gewünschte Abmessung geschliffen wird, bevor die angrenzende zylindrische Fläche auf den korrekten Durchmesser geschliffen wird, und so programmiert ist, um zu erreichen, dass die Schleifscheibe von der in die gewünschte Abmessung geschliffenen Seitenwand zumindest bei Beginn des abschließenden Einstechschliffens des Durchmessers freigestellt wird. 25
24. Schleifmaschine und Steuersystem nach Anspruch 23, wobei die Schleifmaschine zwei Schleifscheiben umfasst, die unabhängig voneinander entlang der X- und der Z-Achse der Maschine gesteuert werden können, wobei jede Schleifscheibe so gesteuert wird, dass sie vor dem abschließenden Teil jedes Schliffs einen schräg geführten Schliff mit anschließendem Freistellen in Querrichtung ausführt. 30

## Revendications

1. Procédé permettant de faire fonctionner une meuleuse (68) comprenant une meule (2) pour meuler une surface cylindrique (8) sur une pièce à usiner (4), la surface cylindrique étant délimitée au niveau 55

d'une ou des deux extrémités par un rebord radial ou une paroi latérale qui doit également être meulé (e) à une dimension appropriée, **caractérisé en ce que** le procédé comprend les étapes consistant à :

- (1) effectuer un meulage en plongée oblique (C, I) à un angle de progression de meulé choisi de façon à ce que le meulage de paroi latérale soit terminé avant le meulage cylindrique, (2) une fois que le meulage de paroi latérale est terminé, écarter (D, J) la meule de la paroi latérale, de façon à ce que seule la surface circonférentielle cylindrique de la meule se mette en prise par meulage avec la pièce à usiner au moins au début de la partie finale du meulage, et (3) meuler en plongée (E, K) la surface cylindrique de la pièce à usiner pour obtenir le diamètre final nécessaire de la surface cylindrique. 10

2. Procédé selon la revendication 1 dans lequel l'écartement est obtenu en déplaçant de manière axiale la meule (2) par rapport à la pièce à usiner (4) dans une direction parallèle à l'axe longitudinal de la surface cylindrique. 15

3. Procédé selon la revendication 1 dans lequel l'écartement est obtenu en déplaçant de manière axiale la pièce à usiner (4) par rapport à la meule (2) dans une direction parallèle à l'axe longitudinal de la surface cylindrique. 20

4. Procédé selon la revendication 2 ou la revendication 3 dans lequel le déplacement axial relatif est arrêté, le déplacement est inversé pour une courte distance pour créer l'écartement et par la suite la trajectoire de la meule est perpendiculaire à la surface cylindrique qui doit être meulée. 25

5. Procédé selon l'une quelconque des revendications 1 à 3 dans lequel durant son déplacement final pour terminer le meulage après avoir créé l'écartement, la meule (2) est avancée le long d'un parcours oblique similaire à celui employé durant la partie précédente du meulage, l'écartement étant tel qu'il empêche un contact avec la paroi latérale durant le déplacement de la meule après l'écartement, et en empêchant ainsi un retrait supplémentaire de métal de la paroi latérale durant l'approche oblique finale de la meule. 30

6. Procédé selon l'une quelconque des revendications 1 à 5 dans lequel durant la partie finale de la plongée la vitesse de travail est réduite par rapport à la vitesse à laquelle elle tourne durant la partie précédente de la plongée avant l'écartement. 35

7. Procédé selon l'une quelconque des revendications 1 à 6 dans lequel durant la partie finale de la plongée 40

le débit de fluide de refroidissement est réduit par rapport à celui qui est employé durant la précédente partie de la plongée avant l'écartement.

8. Procédé selon l'une quelconque des revendications 1 à 7 dans lequel la pièce à usiner (4) est un vilebrequin de moteur à combustion interne. 5
9. Procédé selon la revendication 8 dans lequel les régions cylindrique et de paroi latérale comprennent les surfaces de support pour un palier principal du vilebrequin. 10
10. Procédé selon la revendication 8 dans lequel les régions cylindrique et de paroi latérale comprennent celles associées à un maneton du vilebrequin. 15
11. Procédé selon l'une quelconque des revendications précédentes dans lequel la surface cylindrique (8) est délimitée au niveau des deux extrémités par un rebord radial ou une paroi latérale, et la surface cylindrique et les deux parois latérales sont meulées en utilisant une succession de deux obliques en plongée (C, I) dans lesquels la face latérale de la meule est écartée par rapport à une paroi latérale de la pièce à usiner durant une partie finale de chaque meulage en plongée. 25
12. Procédé selon la revendication 11 dans lequel durant un premier meulage oblique en plongée (C), un taux d'alimentation, des temps d'arrêt, une vitesse de travail, une pression de fluide de refroidissement et un débit sont commandés par rapport à des points d'extrémité du meulage, de façon à ce que la paroi latérale au niveau d'une extrémité, de la surface cylindrique et la partie adjacente de celle-ci soient meulées à la dimension appropriée. 30
13. Procédé selon la revendication 12 dans lequel après le meulage de la paroi latérale et du diamètre par le premier meulage en plongée au niveau d'une extrémité de la surface cylindrique, la meule est rétractée, et un second meulage oblique en plongée (I) est ensuite réalisé cette fois en déplaçant la meule le long d'une trajectoire vers la paroi latérale au niveau de l'autre extrémité de la surface cylindrique, pour meuler ainsi la paroi latérale et le diamètre au niveau de l'autre extrémité de la surface cylindrique. 35
14. Procédé selon la revendication 13 dans lequel la meule est indexée de manière latérale avant que le second meulage oblique en plongée (I) soit réalisé. 40
15. Procédé selon la revendication 14 dans lequel l'indexation latérale n'est pas plus de 2/3 de la largeur de la meule afin d'assurer un chevauchement sur le diamètre entre les plongées. 45

16. Procédé selon la revendication 14 dans lequel la largeur de meule est insuffisante pour que la longueur entière de la surface cylindrique soit meulée au diamètre nécessaire par les deux meulages obliques en plongée (C, I), et au moins un meulage perpendiculaire en plongée (E) est réalisé pour meuler la région centrale de la surface cylindrique (8). 50
17. Procédé selon la revendication 16 dans lequel l'au moins un meulage perpendiculaire en plongée (E) est réalisé entre le premier et le second meulages obliques en plongée (C, I).
18. Procédé selon la revendication 16 dans lequel l'au moins un meulage perpendiculaire en plongée (K) est réalisé après le second meulage oblique en plongée (I).
19. Procédé selon l'une quelconque des revendications 1 à 18 dans lequel une meule profilée après corroyage est employée.
20. Procédé selon la revendication 19 comprenant en outre l'étape consistant à délivrer des informations provenant du après corroyage de la meule et de la position des faces de la meule à un système de commande (100) de la meuleuse (68), le système de commande commandant le meulage des parois latérales et des diamètres à partir de celles-ci.
21. Procédé selon l'une quelconque des revendications 1 à 20 dans lequel la meule a une profondeur de grain égale sur chacune des deux faces latérales, et une profondeur de grain appropriée est choisie pour la face cylindrique de la meule, de façon à ce que si la meule s'use uniformément en fonctionnement, sensiblement tout le grain autour des faces latérales et cylindrique de la meule sera utilisé avant que la meule ne doive être remplacée.
22. Procédé selon la revendication 21 dans lequel le grain de la meule est en CBN.
23. Meuleuse (68) et système de commande assisté par ordinateur programmable (100, 210) pour celle-ci, programmé pour meuler une surface cylindrique (22) délimitée par au moins une paroi latérale radiale (224, 226) sur une pièce à usiner (212) au moyen d'une série de meulages en plongée, **caractérisée en ce que** le système de commande est programmé pour commander une meule (208) de la meuleuse afin de meuler la ou chaque paroi latérale à la dimension appropriée avant que la surface cylindrique adjacente soit meulée au diamètre approprié, et faire que la meule s'écarte de la paroi latérale meulée au moins au début d'un meulage final en plongée du diamètre. 55

- 24.** Meuleuse et système de commande selon la revendication 23, la meuleuse comprenant deux meules de meulage qui peuvent être commandées de manière indépendante le long des axes X et Z de la meuleuse, dans laquelle chaque meule est commandée pour réaliser un meulage oblique avec un écartement latéral après celui-ci, avant la partie finale de chaque meulage.

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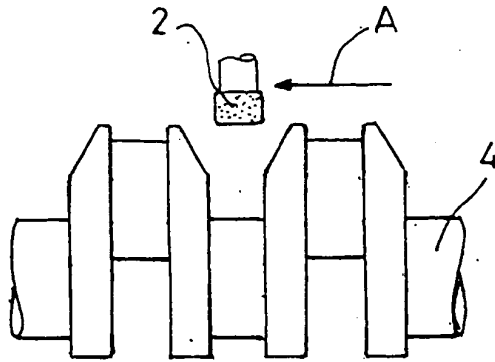


Fig. 1

Fig. 2

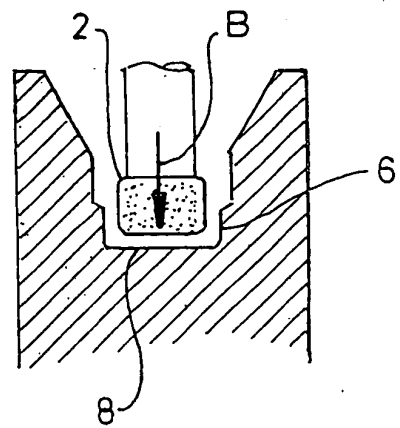


Fig. 3

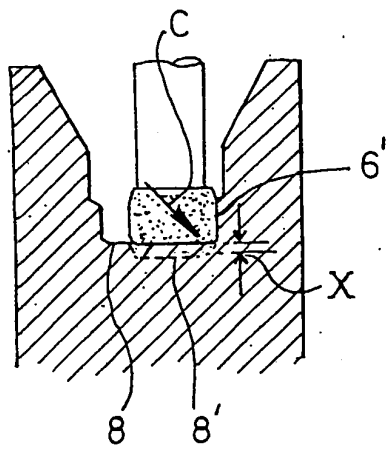
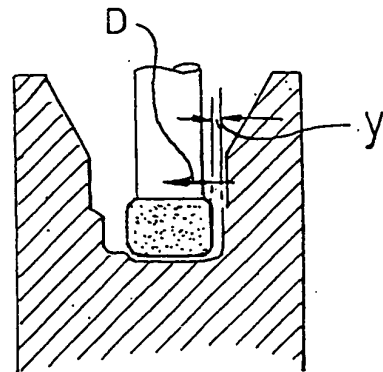


Fig. 4



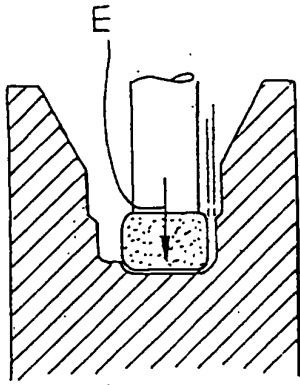


Fig. 5

Fig. 6

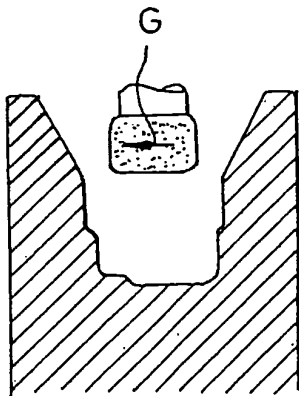
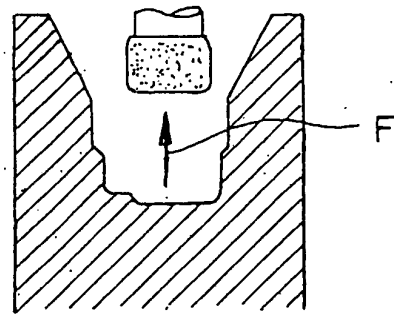
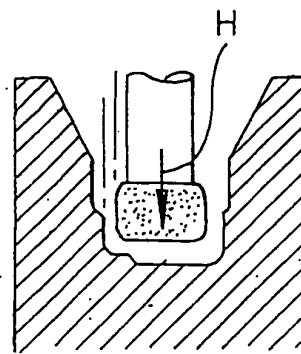


Fig. 7

Fig. 8



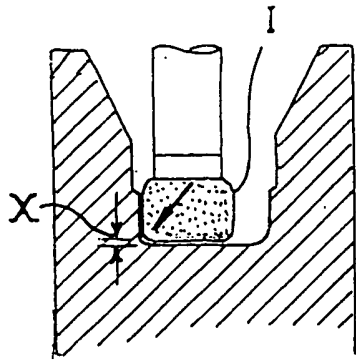


Fig. 9

Fig. 10

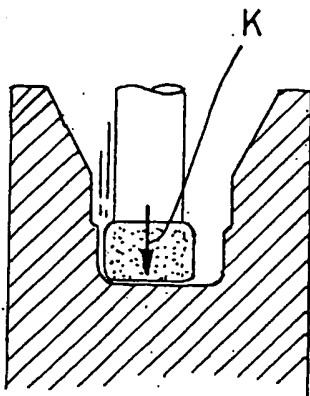
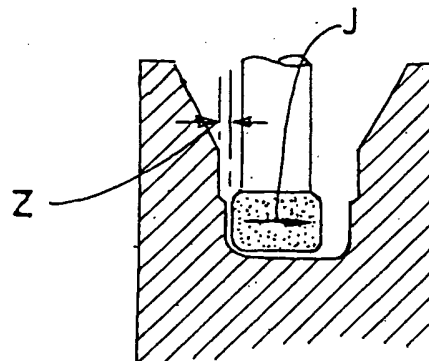
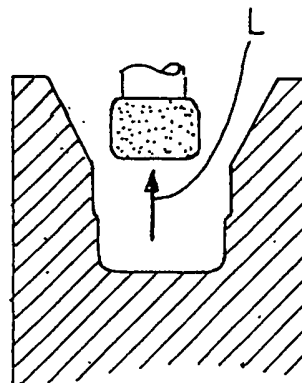


Fig. 11

Fig. 12



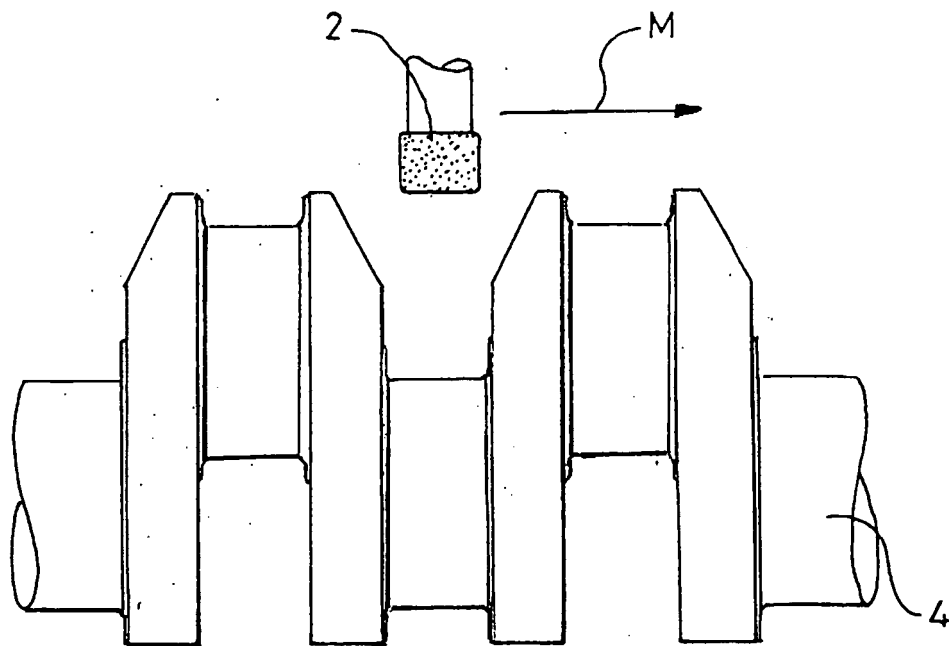


Fig. 13

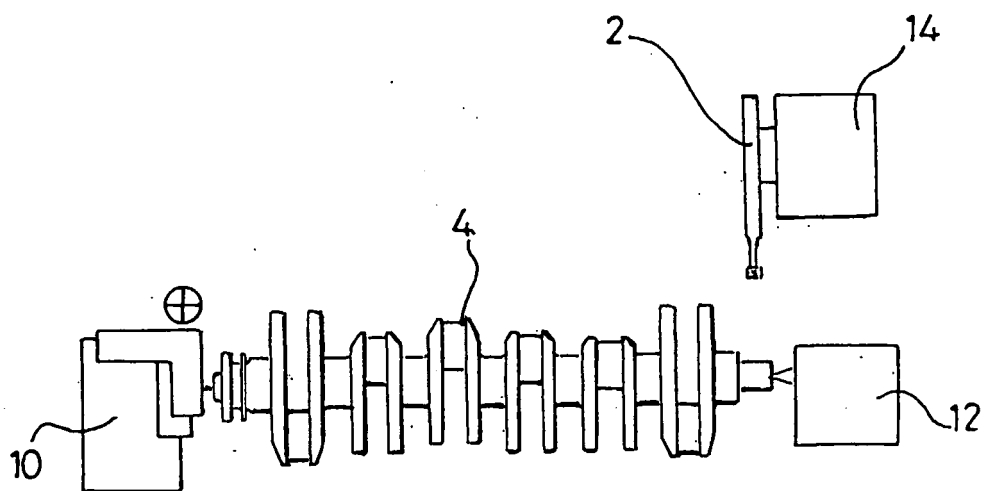


Fig. 14

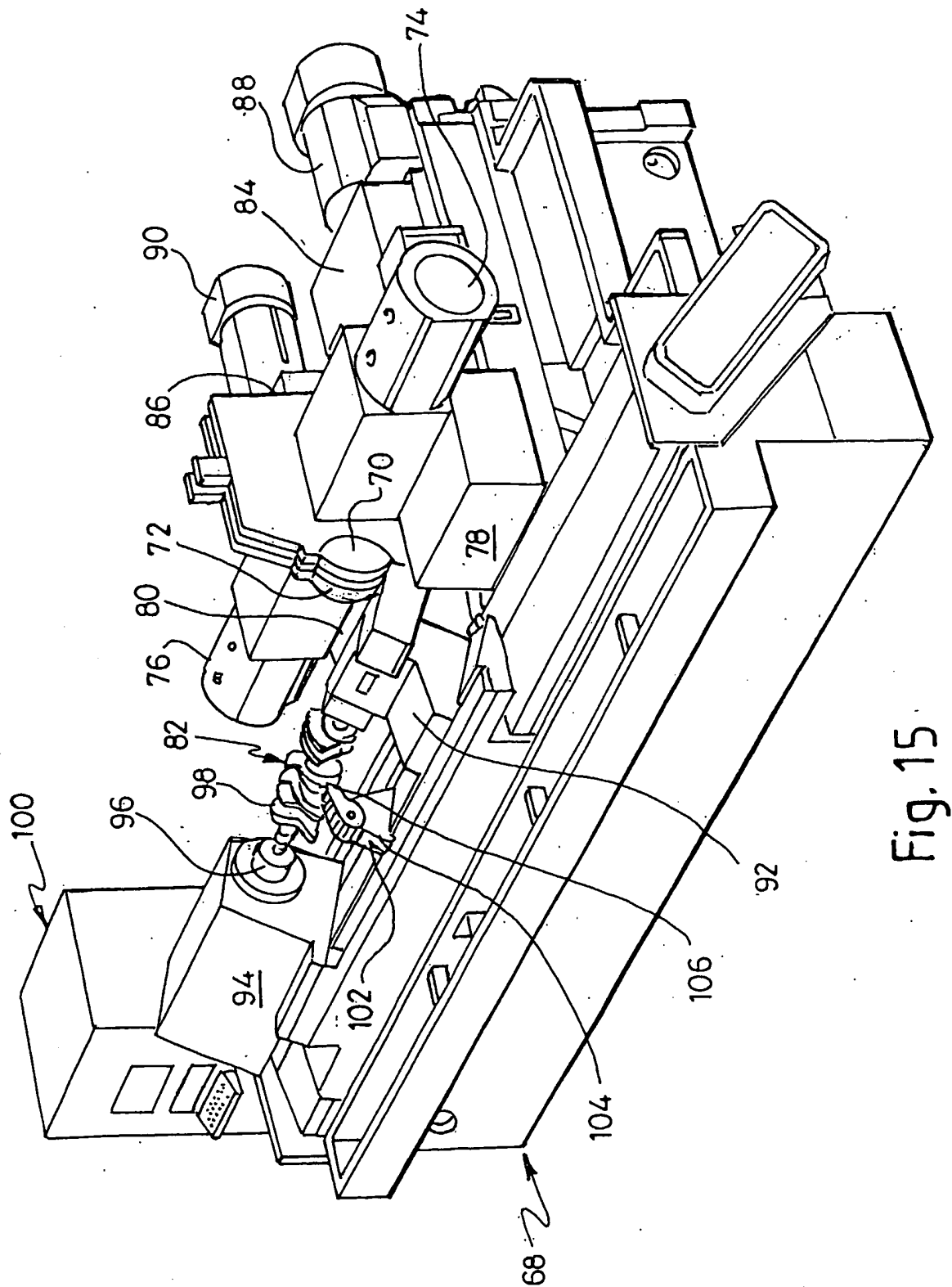


Fig. 15

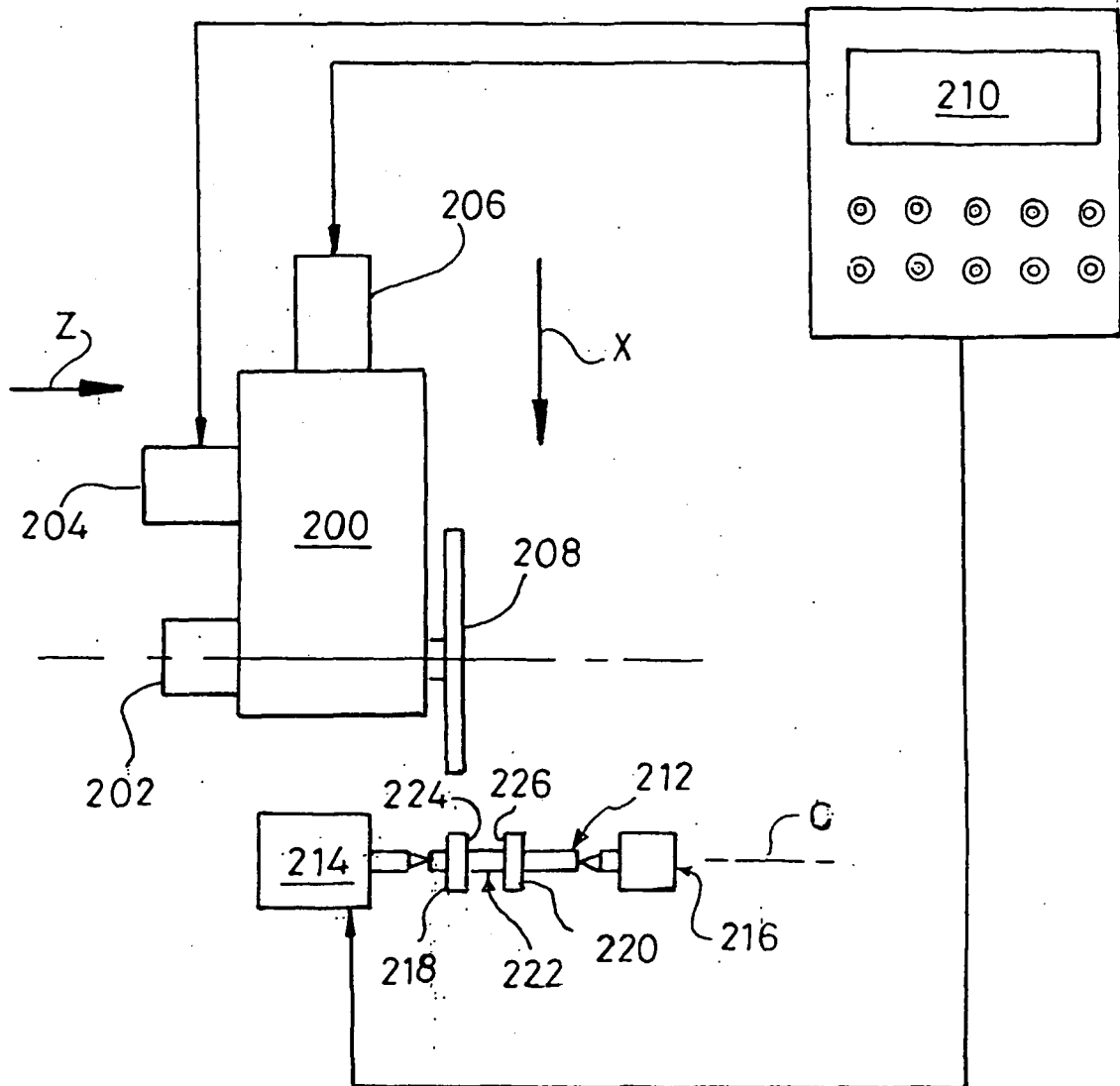


Fig. 16

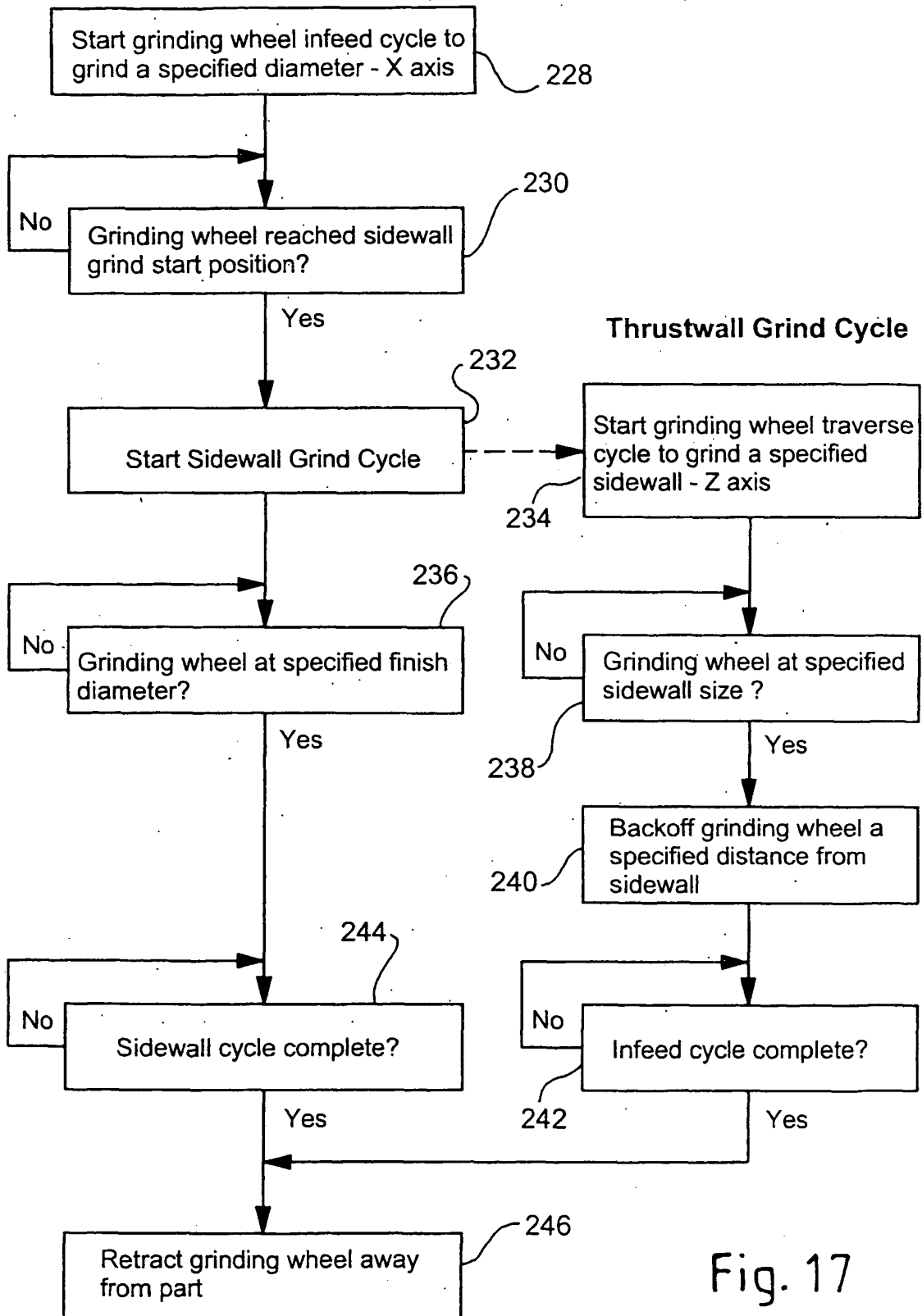
**Diameter & Sidewall Grind Cycle**

Fig. 17

**REFERENCES CITED IN THE DESCRIPTION**

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