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Stevens et al.

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[54] **COPYING MACHINE TOOLS**

[75] Inventors: **Arthur Royden Stevens,** Torquay; **Ronald Forrester Cartwright,** Exminster, both of England

[73] Assignee: **Centrax Limited,** Devon, England

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[30] **Foreign Application Priority Data**

Feb. 8, 1973 United Kingdom 6256/73

[52] **U.S. Cl.** ..... **51/145 R;** 51/101 R; 51/147

[51] **Int. Cl.²** **B24B 21/02;** B24B 21/12; B24B 17/02

[58] **Field of Search** ..... 51/101 R, 135–147

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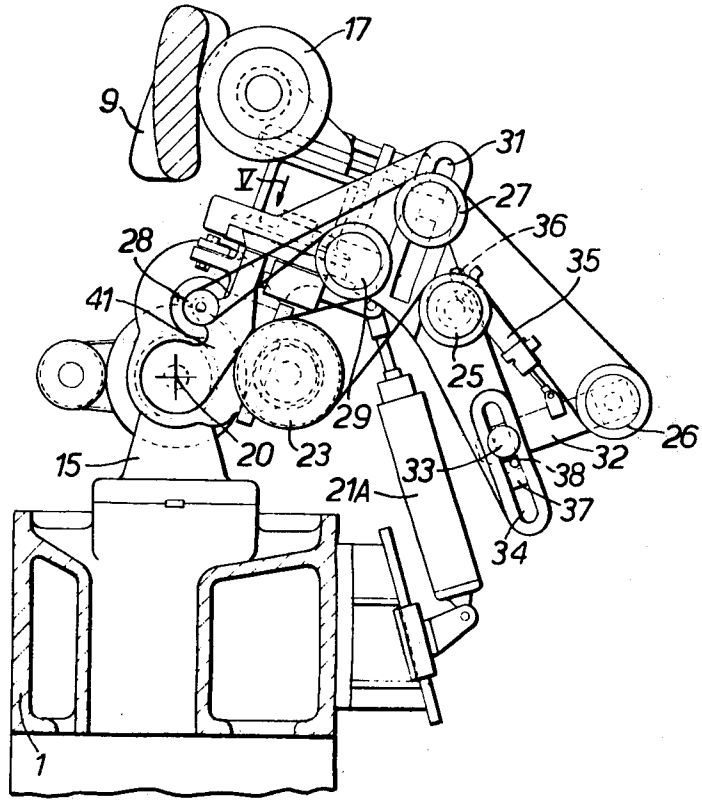
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Primary Examiner—Othell M. Simpson
Attorney, Agent, or Firm—Oblon, Fisher, Spivak, McClelland & Maier

[57] **ABSTRACT**

A polishing machine using an abrasive belt and embodying a copying principle for polishing turbine blades. The belt is driven by an assembly which is pivotally mounted and carries a follower which is pressed against a master cam, while the belt is pressed against the blade blank by a contact wheel mounted on an arm pivoted about the same axis as the drive assembly. The contact wheel arm is spring-loaded relative to the drive assembly so that the belt can move to accommodate oversize portions of the blade blank; a stop limits the movement of the contact wheel arm relative to the drive assembly to prevent the blade becoming undersized.

9 Claims, 6 Drawing Figures



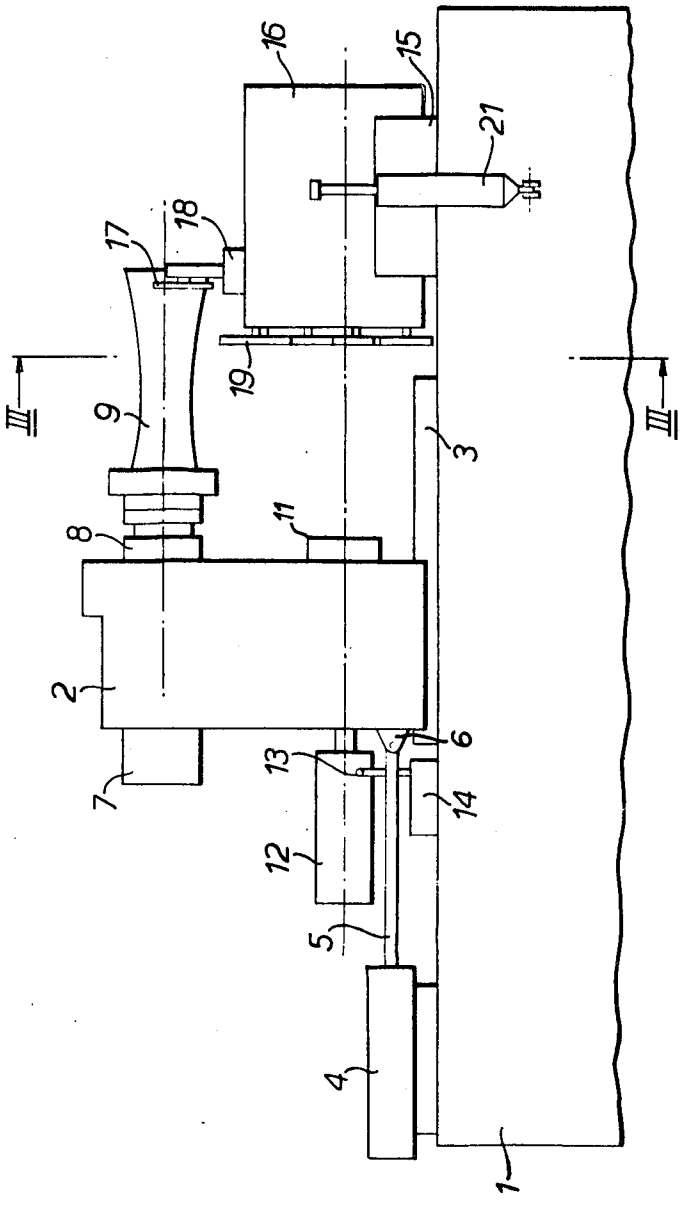


FIG. 1.

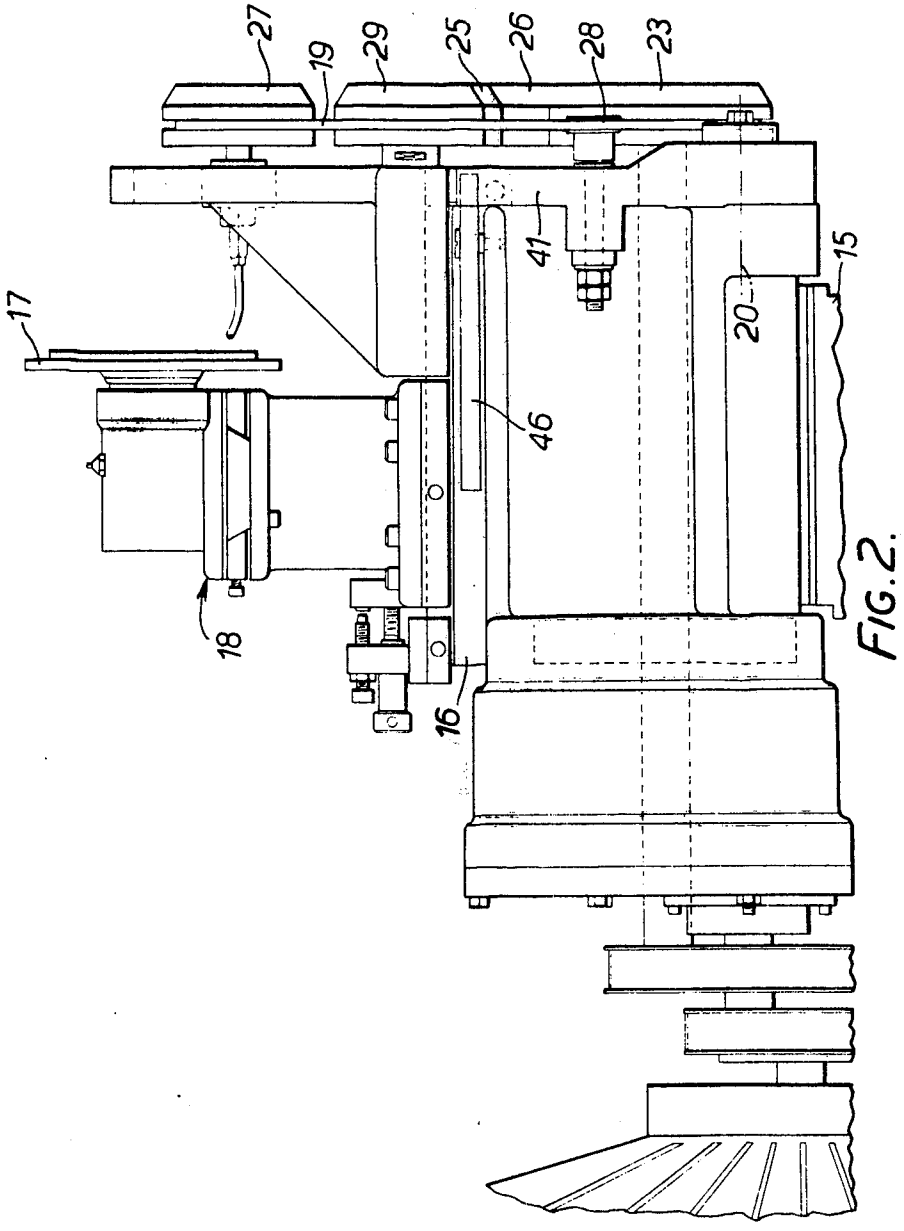


FIG. 2.

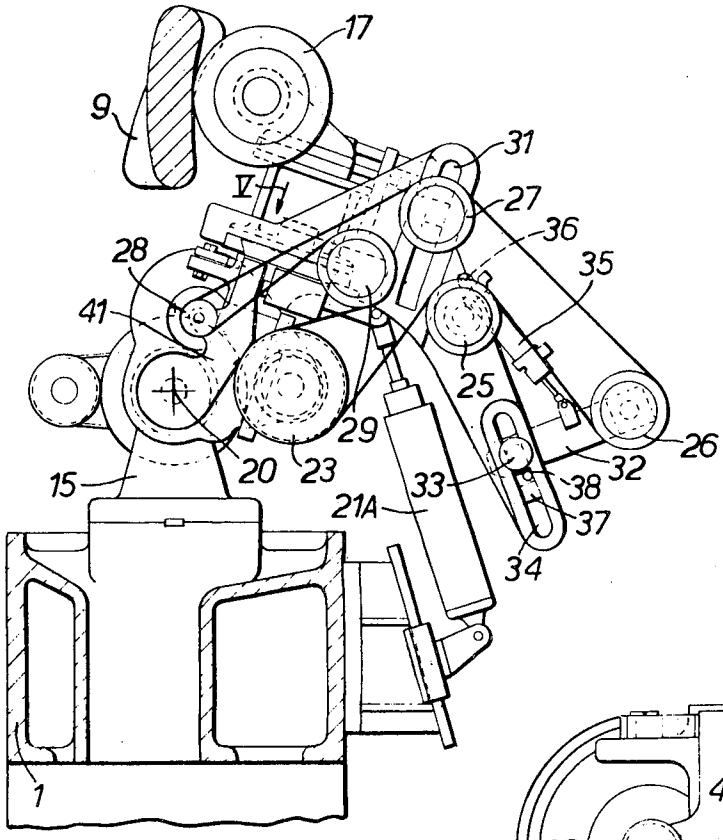


FIG. 3.

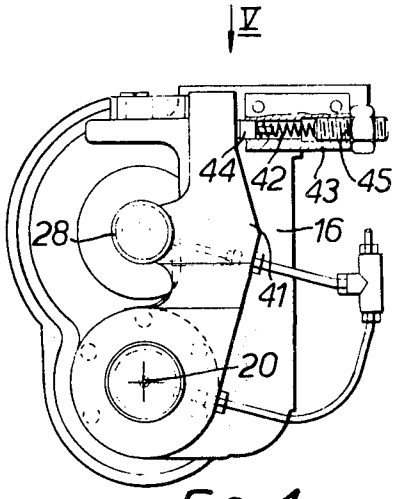


FIG. 4.

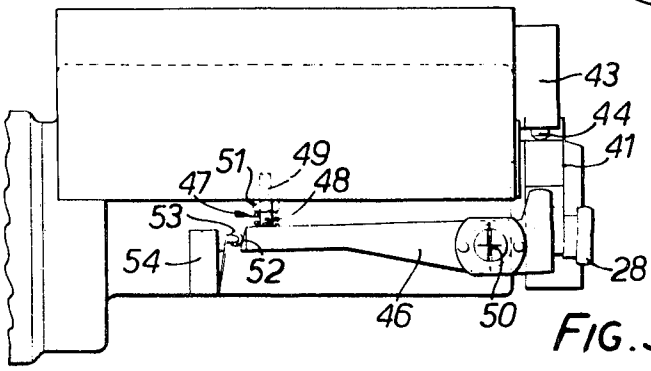


FIG. 5.

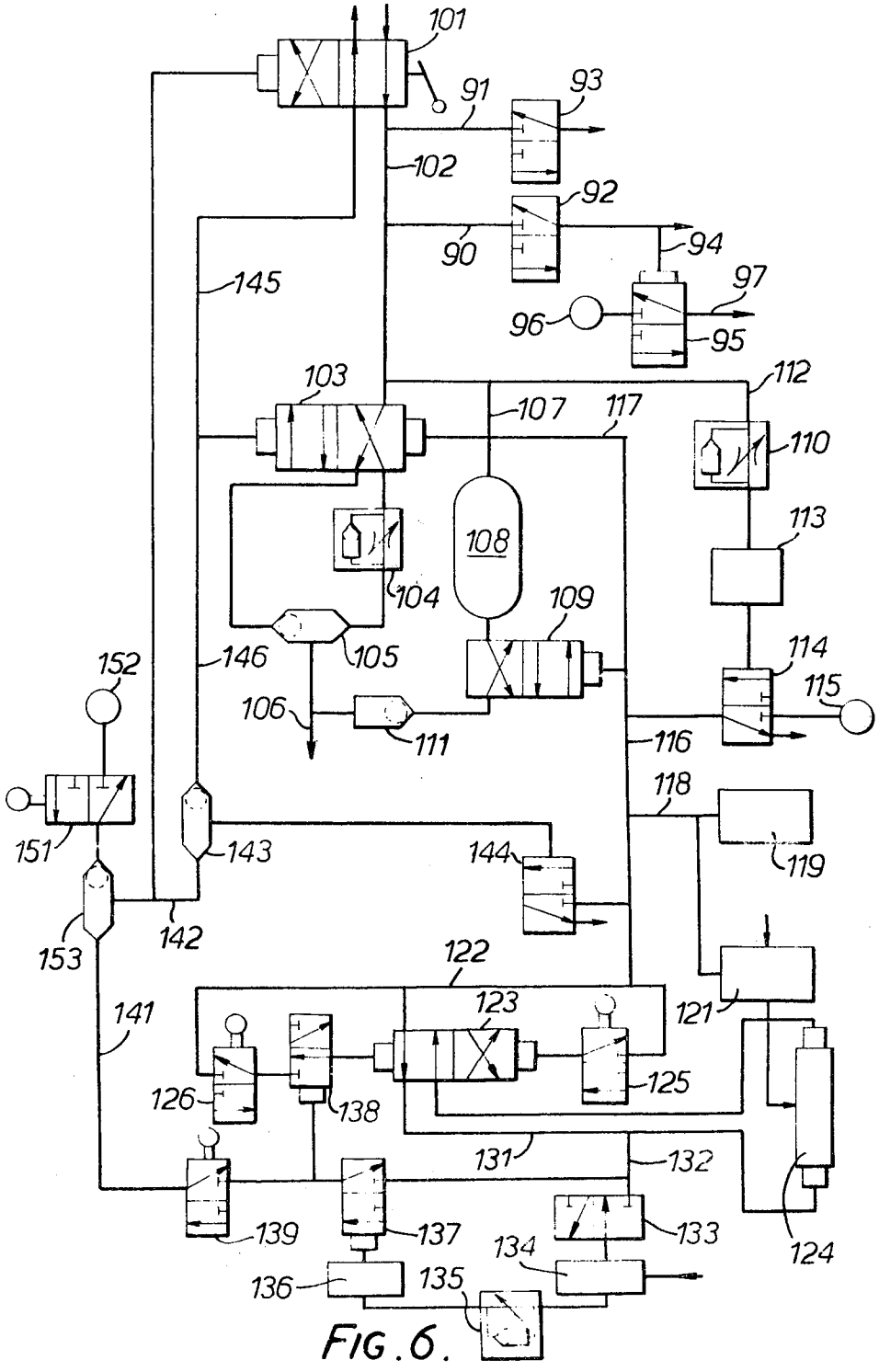

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FIG. 6.

COPYING MACHINE TOOLS

This invention relates to copying machine tools.

According to one aspect of the present invention, a copying machine tool comprises means for mounting a cam and a workpiece for movement in synchronism, a movable member carrying a follower for engagement with the cam and further mounting means for means for removing material from a workpiece in the mounting means, the further mounting means being connected to the movable member by yieldable means which permits the further mounting means to move relative to the movable member when the material-removing means encounters resistance from the workpiece.

The invention is particularly applicable to machines intended for polishing profiled workpieces such as blades for turbines and rotodynamic compressors. Such blades may be machined to approximately their finished shape by one of a number of methods; for example, they may be machined in a milling machine embodying a copying principle. When a blade has been machined, it is necessary to polish the blade to remove the tool marks left by the machining process.

It has been proposed to polish the blades by means of belt grinding machines in which an abrasive belt passes around a contact wheel carried on a pivoted arm which also carries a stylus wheel which engages a cam which extends parallel with the axis of the blade to be polished, the cam and the blade being rotated in synchronism about their axes. At the commencement of the polishing operation the pivot point of the arm is so located that, with the stylus in contact with the cam, the belt on the contact wheel is out of contact with the blade. The pivot point of the arm is then fed in progressively perpendicularly to and towards the plane containing the axes of the cam and blade. When the pivot point reaches its end position the geometry is such that the belt will polish the blade to the profile determined by the cam. This arrangement requires the feeding in of the pivot point of the arm at a rate which has to be controlled by a skilled operator since if the infeed is too rapid with a blade which is oversize in any portion the belt is unable to remove metal satisfactorily at the speed required and breakage of the belt may occur. On the other hand, if the base of the arm is fed in at a speed which will avoid this for an oversize blade, the operation will take longer than is necessary on a blade which requires the removal of less metal to bring it to the required profile.

According to a second aspect of the present invention, a belt polishing machine for polishing a profiled workpiece such as a blade for a fluid flow machine comprises means for mounting a cam and a workpiece for rotation in synchronism and about parallel axes, a pivoted arm carrying a follower for engagement with the cam, means arranged to support and drive a polishing belt, which means include a contact wheel movable with the arm towards and away from a workpiece in the mounting means, the contact wheel being connected to the arm by yielding means which permits the contact wheel to move on the arm when the contact wheel encounters resistance from the workpiece. Preferably the contact wheel is mounted on a second arm which is pivoted about the same axis as the arm carrying the follower. With these arrangements it is no longer necessary to feed the pivot axis of the arms and these can remain stationary. The follower may be moved into

contact with the cam and if the blade or other workpiece is oversize the contact wheel can float and will be pressed against the workpiece by the yielding means such as a spring and will continue to be forced against the workpiece until the contact wheel reaches the final position it would have had if it were fixed to the arm carrying the follower and the pivot axis had been fed in from an out-lying position. Excess removal of metal may be prevented by providing a stop to prevent movement of the contact wheel relative to the arm carrying the follower by the yielding means beyond the said final position.

The apparatus may be made at least partially automatic by providing for continuous passes of the contact wheel axially of the workpiece until the contact wheel reaches the pre-determined position relative to the first arm, indicating that the workpiece has been brought to size. For example, this may be achieved by a position-conscious device such as a micro-switch carried by the first arm and engaged by an abutment moving with the contact wheel.

Preferably, rotation of the cam and the workpiece are varied around the periphery of the cam and workpiece, the speed being controlled by a three-dimensional cam. In this way it is possible for the workpiece to rotate rapidly where the quantity of metal to be removed is small, for example around the trailing and leading edges of the blade, and for it to rotate slowly where the amount of metal to be removed is likely to be high, for example along the faces and particularly the concave face of the blade.

The invention may be carried into practice in various ways but one blade polishing machine will now be described by way of example with reference to the accompanying drawings, in which:

FIG. **1** is a much simplified side elevation of the machine;

FIG. **2** is a side elevation of the belt drive assembly seen from the opposite side from FIG. **1**;

FIG. **3** is an end elevation of the belt drive assembly on the line III—III in FIG. **1**.

FIG. **4** is a view similar to FIG. **3** on a somewhat larger scale showing the arm carrying the contact wheel;

FIG. **5** is a plan view of the arm carrying the contact wheel seen in the direction of the arrows V in FIGS. **3** and **4**; and

FIG. **6** is a circuit diagram of the pneumatic control circuit of the apparatus.

As seen in FIG. **1**, the polishing machine comprises a bed **1** on which is mounted a travelling headstock **2** which can be reciprocated on longitudinal guides **3** by an actuator comprising a hydraulic cylinder **4** which is fixed to the bed **1** and a piston rod **5** connected at **6** to the headstock **2**. The headstock carries a hydraulic motor **7** which drives a first face plate **8** carrying a cam **9** by clamps which enable the position of the cam **9** on the face plate **8** to be adjusted and a second face plate **11** which carries the blade to be polished. The headstock includes gearing by which the motor **7** drives the two face plates **8** and **11** at the same speed and in the same direction. The spindle on which the face plate **11** is mounted carries at its other end a three-dimensional speed cam **12** which is sensed by a follower **13** which controls a valve **14** which adjusts the flow of hydraulic fluid to the motor **7** so that the cam **12** controls the instantaneous rate of rotation of the face plates **8** and **11**.

Fixed to the bed 1 is a mounting block 15 on which is pivoted a belt drive assembly 16 which carries a stylus wheel 17 by mounting means 18 which permit the position of the stylus wheel relative to the drive assembly 16 to be adjusted. The assembly 16 also includes a number of pulleys on which is mounted an endless abrasive belt 19. The drive assembly 16 can be moved as an arm about its pivot axis 20 on the block 17 by a pneumatic piston-and-cylinder assembly 21 so as to move the stylus wheel 17 into contact with the cam 9 and to move the abrasive belt into contact with a blade carried in the face plate 11.

As can be seen in FIG. 3, the abrasive belt 19, which is an endless flexible belt having abrasive particles secured to it by adhesive, passes around a drive pulley 23 which is driven by a hydraulic motor via an input shaft coincident with the pivot axis. The belt also passes around idler pulleys 25, 26, 27, a contact wheel 28 and a further idler pulley 29. The idler pulley 27 is mounted for occasional adjustment in a slot 31 and the idler pulley 26 is mounted on an arm 32 which is pivotable about a shaft 33 mounted on a block which is occasionally adjustable in a slot 34. Tension in the belt is maintained by pressure in a piston-and-cylinder assembly 35 extending between the arm 32 and a fixed point 36 on the belt drive assembly 16. A micro-switch 37 is mounted in the slot 34 and has a feeler 38 which engages the arm 32. If the belt 19 should break, the arm 32 moves rapidly in a clockwise direction (as seen in FIG. 3) so as to close the micro-switch 37, and thus stop the machine. A pneumatic valve could be used in place of the micro-switch 37.

As can be seen in FIG. 3, and as can be seen in more detail from FIG. 4, the contact wheel is mounted on a contact wheel arm 41 which is pivotable about the pivot axis 20 of the belt drive assembly 16. The contact wheel arm 41 is biased in an anti-clockwise direction as seen in FIGS. 3 and 4, i.e. towards the blade to be polished, by a spring 42 which is contained in a block 43 mounted on the belt drive assembly 16, and has a sliding plunger 44 at one end to engage the contact wheel arm 41 and an adjustable screw 45 at the other end by which the pressure applied by the spring to the arm can be adjusted. As can be seen in FIG. 5, the upper end of the contact wheel 41 abuts against one end of a finger 46 which extends in a direction parallel with the pivot axis 20 and is pivoted about an approximately vertical axis 50. The finger 46 can engage at its other end with an adjustable stop 47 formed by a screw 48 in a tapped hole 49 in the belt drive assembly 16, the position of the screw 48 being locked by a nut 51. The outer end face of the finger 46 is formed with a cam surface 52 which engages a follower 53 on a micro-switch 54.

Operation of the apparatus so far described is as follows. During polishing, the cam 9 and the blade carried in the face plate 11 are rotated about their axes continuously and at a speed determined by the three-dimensional speed cam 12 and the headstock is continuously reciprocated by the hydraulic cylinder 4. When polishing is to commence, the piston-and-cylinder assembly 21 pivots the belt drive assembly 16 at a controlled speed in a direction which is counter-clockwise in FIG. 3 until the stylus wheel 17 engages the cam 9 whereupon full pressure is supplied to the assembly 21. Shortly before this engagement occurs, and assuming that the blade is slightly oversize, the belt passing around the contact wheel 28 will engage the blade. The spring 42 will yield so that the rotational movement of the contact wheel about the pivot axis 20 will slightly lag on the belt drive assembly 16 and the pressure with which the belt is applied to the blade will depend upon the amount by which the spring 42 is compressed and the tension on the belt. The headstock will continue to be reciprocated and metal will continue to be removed from the blade progressively until the finger 46 engages the stop 47. At this stage the axes of the stylus wheel 17 and the contact wheel 28 and the pivot axis 20 will be in line and accordingly the blade will be brought to the size determined by the shape of the cam. At this time the micro-switch 54 will be actuated by the cam 52 and this, in conjunction with a preset time delay set to the blade length, will cause the machine to cease operation at the end of the next return stroke of the piston and cylinder 4, 5 whereupon the piston-and-cylinder assembly 21 will retract to return the belt drive assembly 16 to its initial position.

The operations of the apparatus described are controlled by a pneumatic system, the circuit of which is shown in FIG. 6, only the more important parts of which will be described in any detail.

Operation of the apparatus is controlled by a hand-operated start valve 101 which, when it is opened, passes air along a line 102. Immediately the valve 101 is opened, air flows from the line 102 along lines 90 and 91 to operate valves 92 and 93 respectively which start the belt drive motor and the coolant supply pump. These valves remain open the whole time the machine is in operation. Air which is passed through the valve 92 also passes along a line 94 to open a valve 95 so that air is supplied from a source 96 along a line 97 to a fog lubricator which supplies mist lubrication to the bearings of the apparatus. Air from the line 102 also passes through a two-position valve 103 and thence through a flow regulator 104 and a shuttle valve 105 to a line 106 leading to the piston-and-cylinder assembly 21 which causes the belt drive assembly 16 to rise at the speed determined by the flow regulator 104 until the stylus wheel 17 is in contact with the cam 9. Immediately the start valve 101 is opened, air also passes through a line 107 to charge a reservoir 108 which is connected through a valve 109 and a non-return valve 111 to the line 106. On opening of the start valve 101, air also passes along a line 112 through a flow regulator 110 to a time delay reservoir 113. After the pressure in the reservoir has reached a pre-determined level, which occurs shortly after the stylus wheel has engaged the cam, the pressure changes over a valve 114 which connects an air source 115 to a line 116. One branch 117 of this line leads to the valve 103 to change over this valve so that the line 102 by-passes the flow regulator 104 and is fed directly into the line 106. The branch 117 also leads to the valve 109 which is changed so that the reservoir 108 is also connected to the line 106, the pressure in which is therefore line pressure, so that the full pressure load is applied to the stylus wheel. The reservoir provides reserve power to enable the cam to follow rapid changes of profile.

Air also passes from the line 116 through a branch line 118 to a valve 119 which controls hydraulic off and on flow to the motor driving the cam head and the work head and an off and on hydraulic valve 121 controlling the supply of hydraulic fluid to the valve controlling the cylinder and piston actuator 4, 5 reciprocating the headstock.

Air also passes from the line 116 through a branch line 122 to a slide valve 123 which controls a hydraulic

change-over valve **124** which determines the direction of feed of the headstock. The slide valve **123** is under the control of limit valves **125** and **126** operated by movements of the headstock so that when the machine is in operation the headstock is reciprocated continuously.

When the slide valve **123** is in position to supply air along the line **131** to the hydraulic change-over valve **124** so as to hold this valve in condition for return travel of the headstock, air also passes along a line **132** through a normally open valve **133** to a normally closed solenoid valve **134** which is controlled by the micro-switch **54** controlled by the finger **46** on the arm **41** carrying the contact wheel **28.** When the workpiece has been brought to size and the micro-switch is operated, the valve **134** opens to allow flow on the return stroke of the headstock through a flow regulator **135** to a reservoir **136.** When pressure in the reservoir has built up to a pre-determined level, a valve **137** is opened and this produces flow from the line **132** to a valve **138** which deprives the slide valve **123** of control by the limit valve **126** and supplies air to a limit valve **139** which is located adjacent the inner end of the headstock travel. When the valve **139** is actuated, air flows from the reservoir **136** through the valve **139** to a line **141** which leads through a shuttle valve **153** to the start valve **101** which is immediately changed over. This causes operation of all the hydraulic pumps to cease and causes air to be supplied through a line **145** to reset the valve **103,** and through a line **146** and a shuttle valve **143** to change over a valve **144** which vents the pressure from the lines **116, 117, 118** and **122.** Air from line **141** also travels along a line **142** through the shuttle valve **143** to ensure change-over of the valve **144.**

On the occurrence of a broken belt, operation of the micro-switch **37** controlled by the tensioning arm **32** opens a valve **151** which causes air to travel from a source **152** through the shuttle valve **153** to the start valve **101** to stop the machine immediately. The machine can be stopped at any time by manual operation of the valve **101.**

The control system has been described in its automatic mode of operation. However, provision is made for the various procedures to be controlled individually and manually if required.

We claim:

1. In a belt grinding machine for grinding a profiled surface of a workpiece, including a supporting structure, means carried by said supporting structure and mounting a cam having a profiled surface and a workpiece for movement in synchronism, a member also carried by said supporting structure and relatively movable toward and away from said profiled surfaces of said cam and said workpiece, a follower mounted on said movable member for engagement with said profiled surface of said cam, biasing means connected between said movable member and said supporting structure for pressing said follower against said profiled surface of said cam, an abrasive belt, belt supporting means carried by said movable member for supporting and driving said abrasive belt to remove material from said profiled surface of said workpiece under the control of said cam, said belt supporting means including a belt contact wheel around which said abrasive belt passes and by which said abrasive belt is pressed against said profiled surface of said workpiece, the improvement comprising:

further mounting means carrying said belt contact wheel, said further mounting means being movable relative to said driving means toward and away from said profiled surface of said workpiece;

stop means carried by said movable member and limiting the movement of said further mounting means relative to said movable member in the direction towards said profiled surface of said workpiece; and

yielding means connected between said further mounting means and said movable member for urging said further mounting means to carry said belt contact wheel and said abrasive belt in the direction towards said profiled surface of said workpiece, said yielding means being incapable of transmitting to said further mounting means the whole of the force applied to said movable member by said biasing means;

whereby said follower is held in engagement with said profiled surface of said cam by said biasing means even in the event that said belt contact wheel and said abrasive belt encounter resistance from said profiled surface of said workpiece, said yielding means yielding to permit movement of said further mounting means and said belt contact wheel relative to said movable member in the direction away from said profiled surface of said workpiece.

2. A belt polishing machine for polishing a profiled surface of a workpiece, comprising:

a supporting structure;

means carried by said supporting structure for mounting a workpiece for rotation about an axis;

an arm mounted on said supporting structure for pivoting movement about an axis parallel to said axis for movement toward and away from said profiled surface of said workpiece;

a follower carried by said pivoted arm;

further mounting means carried by said supporting structure for mounting a cam having a profiled surface for rotation about an axis parallel to said pivot axis of said pivoted arm in synchronism with the rotation of said workpiece, said further mounting means being located to support said cam with said profiled surface of said cam positioned to be engaged by said follower as said pivoted arm moves toward said profiled surface of said workpiece;

biasing means connected between said supporting structure and said pivoted arm for moving said pivoted arm to press said follower against said profiled surface of said cam;

a polishing belt;

belt supporting means carried by said pivoted arm for supporting and driving said polishing belt, said belt supporting means including a contact wheel which is movable relative to said pivoted arm, around which contact wheel said polishing belt passes, and by contact wheel said polishing belt may be pressed against said profiled surface of said workpiece, and a stop member carried by said pivoted arm for limiting the movement of said contact wheel relative to said pivoted arm in the direction towards said profiled surface of said workpiece, and

yielding means connected between said contact wheel and said pivoted arm for urging said contact wheel to press said polishing belt against said profiled surface of said workpiece, and being incapable of transmitting to said contact wheel the whole of the force applied to said pivoted arm by said bi-

asing means,

whereby said follower is held in engagement with said profiled surface of said cam by said biasing means even in the event that said contact wheel and said polishing belt encounter resistance from said profiled surface of said workpiece, said yielding means yielding to permit movement of said contact wheel relative to said pivoted arm in the direction away from said profiled surface of said workpiece.

3. A polishing machine according to claim **2** which further includes:

sensing means responsive to the position of said contact wheel relative to said pivoted arm and having a first condition and a second condition relating respectively to first and second positions of said contact wheel relative to said arm, movement of said contact wheel from said first position to said second position corresponding to a movement of said contact wheel towards said profiled surface of said workpiece; and

control means controlling the operation of said machine in response to signals from said sensing means whereby said machine is stopped when said sensing means assumes said second condition for more than a predetermined period.

4. A polishing machine according to claim **2** which further includes:

a second arm pivoted about the same axis as said pivoted arm carrying said follower, said contact wheel being mounted on said second arm.

5. A polishing machine according to claim **2** which further includes:

a pivot on said cam carrying said follower; and

a lever mounted on said pivot,

said lever having first abutment means for engagement with said stop member and second abutment means for engagement with said second arm, said second abutment means being closer to said pivot than is said first abutment means.

6. A polishing machine according to claim **5** which further includes:

a sensor mounted on said arm carrying said follower, adjacent said stop member, said sensor being responsive to the position relative to said arm carrying said follower, of a portion of said lever adjacent said first abutment means, and having first and second conditions relating respectively to first and second positions of said lever relative to said arm carrying said follower, movement of said contact wheel from said first position to said second position corresponding to a movement of said contact wheel towards said profiled surface of said cam; and

control means controlling the operation of said machine in response to signals from said sensor, whereby said machine is stopped when said sensor assumes said second condition for more than a predetermined period.

7. A polishing machine according to claim **2** wherein:

said mounting means for said cam and said workpiece are reciprocably mounted on said supporting structure for movement relative to said belt supporting means in a direction parallel to said axes of said mounting means.

8. A polishing machine according to claim **2** which further includes:

a peripheral speed cam;

mounting means carried on said supporting structure for mounting said peripheral speed cam for rotation in synchronism with said first-mentioned cam and said workpiece;

a follower movably mounted adjacent said peripheral speed can on said supporting structure to move under the control of said peripheral speed cam; and

speed control means controlling the speed of rotation of the mounting means for said workpiece, said first-mentioned cam, and said peripheral speed cam in response to the position of said follower.

9. A polishing machine according to claim **8** wherein:

said mounting means for said workpiece, said first-mentioned cam, and said peripheral speed cam are reciprocably mounted on said supporting structure relative to said belt supporting means and said follower in a direction parallel to said axes of said mounting means for said workpiece and said first-mentioned cam, the axis of rotation of said mounting means for said peripheral speed cam being parallel to said direction of reciprocation.

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