Feb. 18, 1969 G. N. LEVESQUE ET AL 3,427,755

COUNTER-FORCE MOTIVATED BACK REST

Filed Dec. 20, 1965 Sheet 1 of 3

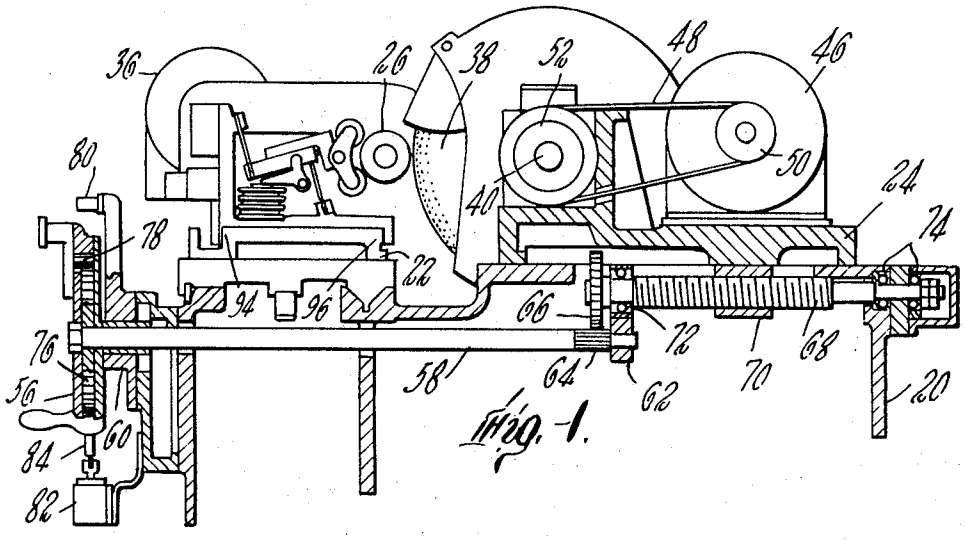


Fig. 1.

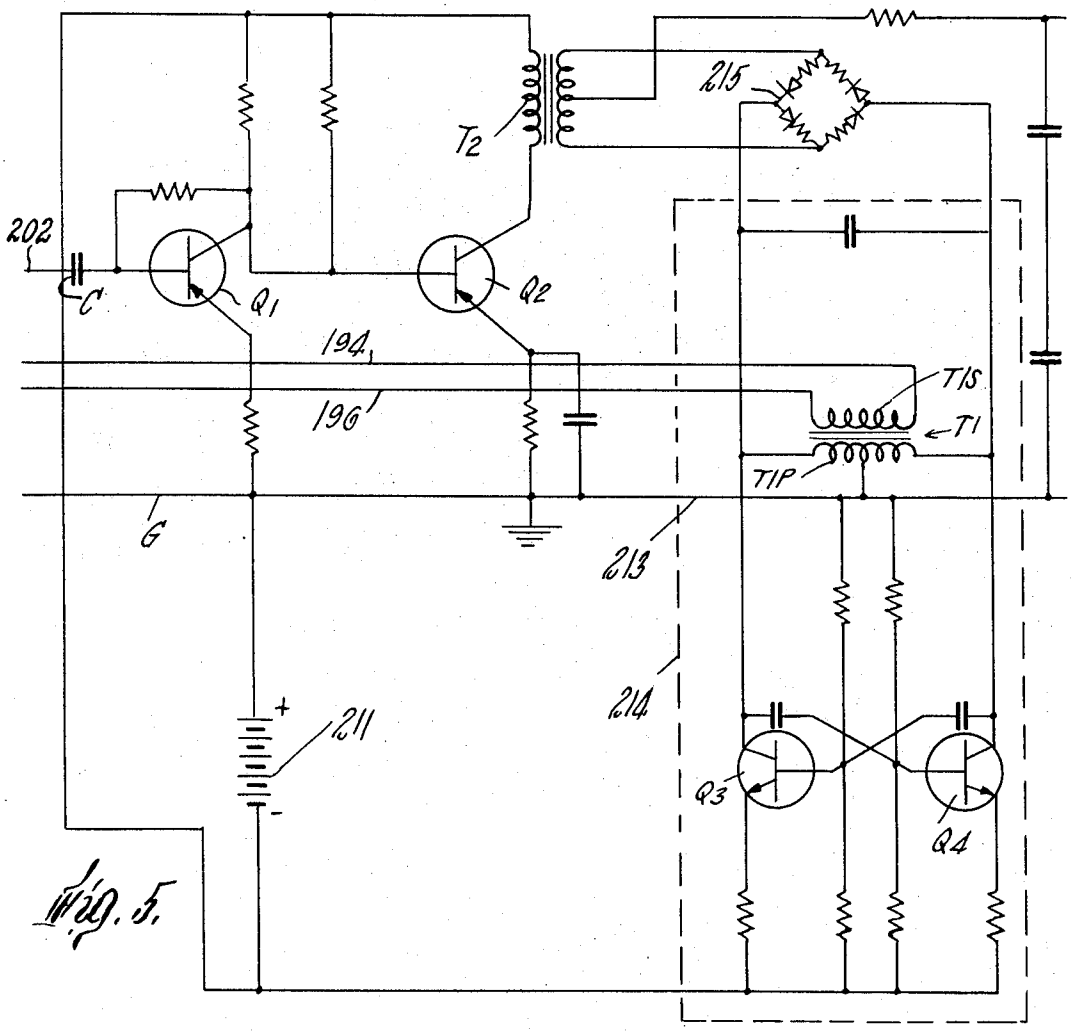


Fig. 5.

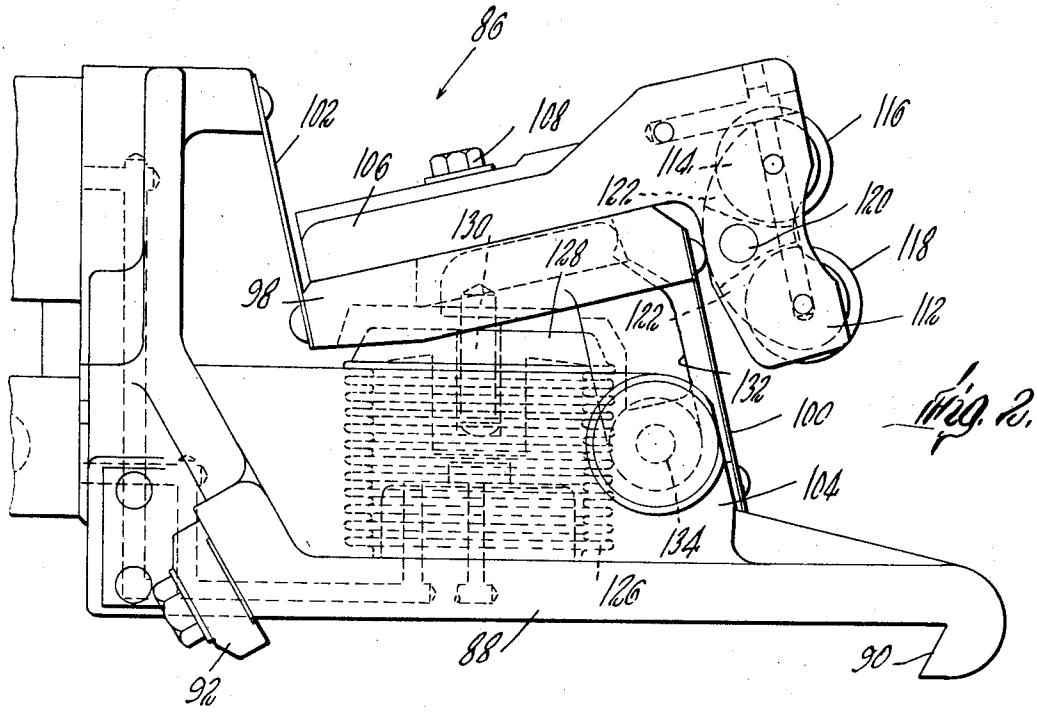

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Fig. 2.

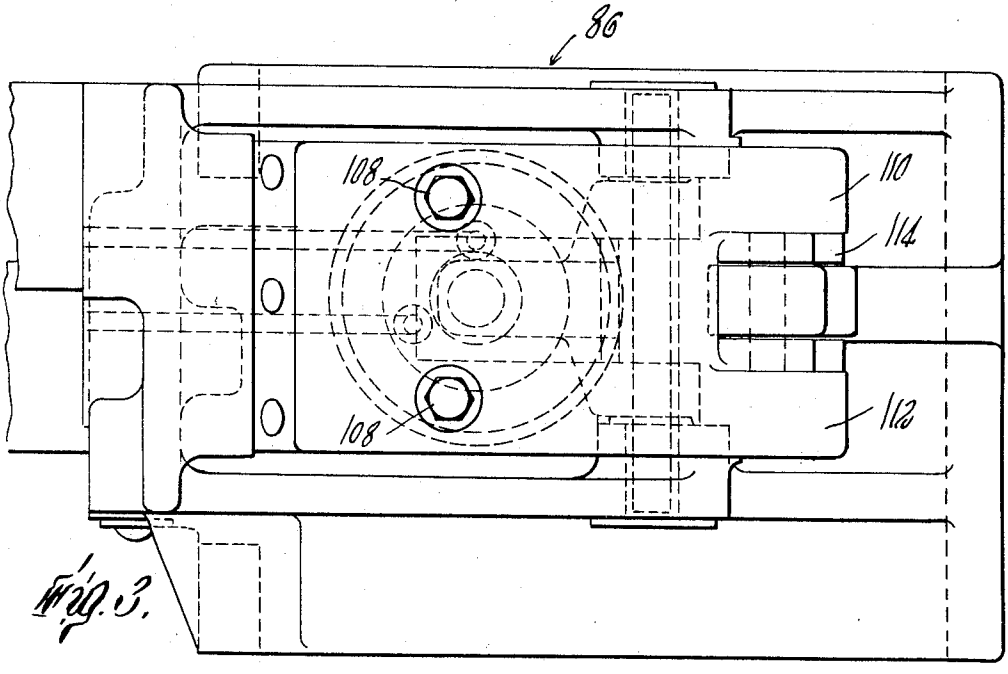

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Fig. 3.

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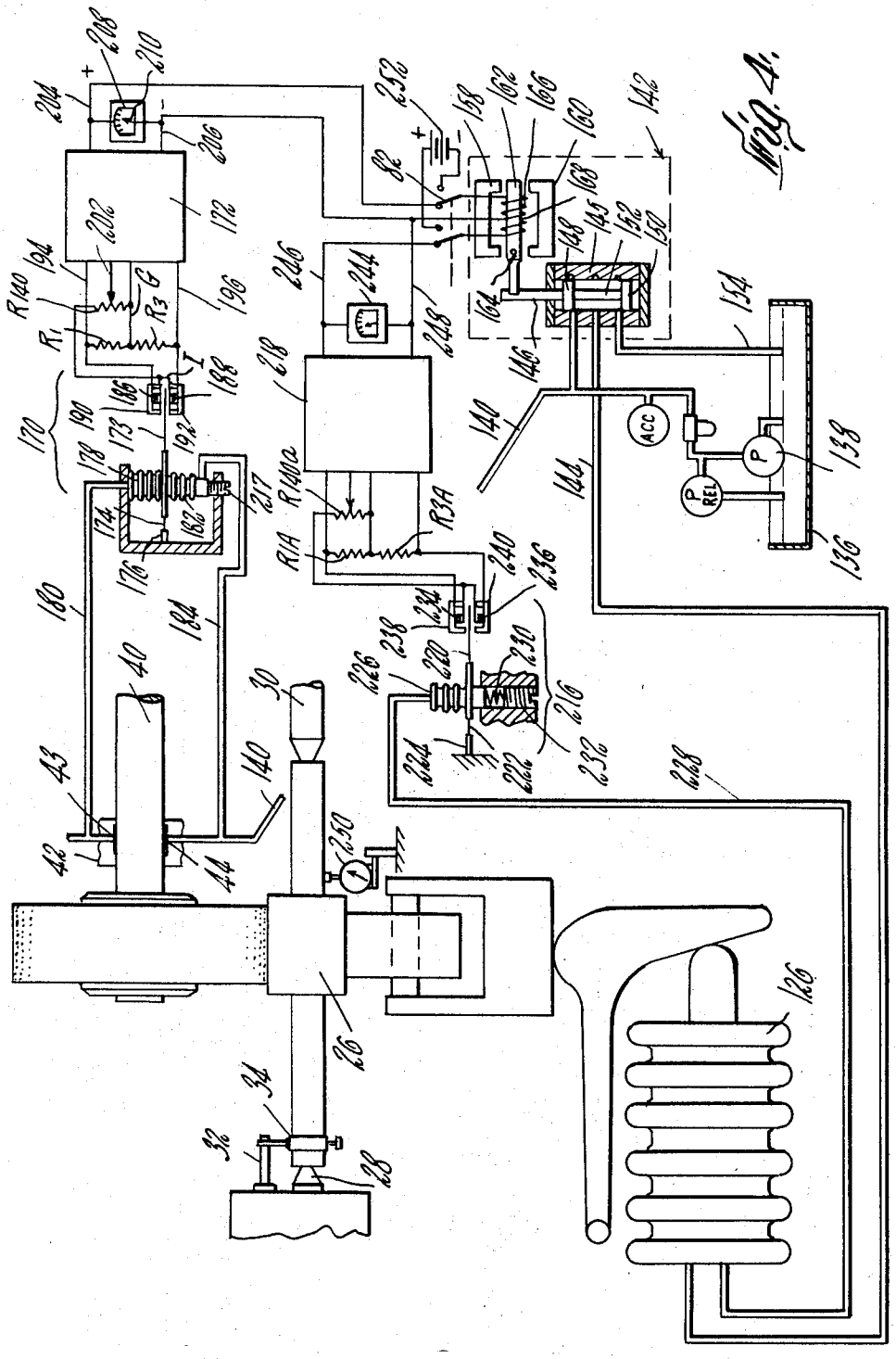


Fig. 4.

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COUNTER-FORCE MOTIVATED BACK REST

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U.S. Cl. 51—105 10 Claims
Int. Cl. B24b 5/00, 17/00, 49/00

ABSTRACT OF THE DISCLOSURE

A counter-force motivated back rest for a cylindrical grinding machine, having a grinding wheel assembly including a grinding wheel, a grinding wheel support and power means for driving the grinding wheel, a rotatable work support, and means for relatively moving said supports to advance the grinding wheel against the work, which comprises "a support on which the back rest is movable against the rotating work in a direction opposed to the force of the grinding wheel, means for applying pressure to force said back rest against the work, a device for sensing and for signalling variable loading stresses within said grinding wheel assembly produced by engagement of the grinding wheel with the work, and a control device for controlling the pressure exterted against the back rest responsive to said signalled unbalance of pressure for regulating said back rest applied pressure to apply a counter-force against the work piece proportionate to said pressure unbalance."

In a preferred form of the invention a device is provided to sense and to signal any unbalance of pressure in opposed hydrostatic pressure pockets corresponding with the engaging force of the grinding wheel against the workpiece, a device for signalling the force applied to force the back rest against the work, and a servo-valve for controlling the force applied to force the back rest against the work, including a device controlled by a signalled increase of hydrostatic pressure unbalance to open said valve and by the signalled increase of the force applied to force the back rest against the work to close said valve, thereby moving said valve to a position in which said signals are in balance.

The present invention relates to an improved back rest mechanism for supporting a rotating work piece in a cylindrical grinding machine, and more particularly to a device for controlling the back rest to apply a counter-force to the rotating work piece which is equal and opposite to the force exerted by the grinding wheel against the work.

Certain features of the illustrated construction which relate specifically to a hydrostatic bearing load signalling device form the subject matter of co-pending application Ser. 446,615 filed Apr. 8, 1965, now issued as Patent No. 3,365,711 dated Jan. 23, 1968 for Hydrostatic Bearing Load Signalling Device. Claims to such features have for this reason been omitted from the present application.

The back rest, which provides support for the rotating work piece held between centers against the thrust of a relatively advancing grinding wheel, is normally adjusted to a position in which the rotating work piece is solidly supported against the grinding wheel to avoid distortions or dislocations of the work. Devices heretofore devised, have been found deficient in that they do not adequately compensate for the variations in grinding force generated by changes in the rate of stock removal as the work piece rotates and is reduced in diameter during grinding, with

the result that the grinding wheel must be fed slowly to obtain satisfactory roundness and concentricity.

In accordance with the present invention it is proposed to press the back rest continuously against the rotating work piece at a pressure, which is controlled to cause the back rest to exert a counter-force against the work piece which is always equal and opposite to the force exerted by the grinding wheel against the work piece.

It is an object of the invention to provide a signal controlled back rest counter-force balancing device, which will detect and signal the force exerted against the workpiece by the grinding wheel, will cause a counter force to be applied against the workpiece in an opposite direction, and will by a comparison of the opposing forces regulate the counter force applied to maintain a balance between said forces.

More specifically, it is an object of the invention to provide a back rest counter-force balancing device adapted to be controlled by the signalled unbalance of a hydrostatic spindle bearing to engage the back rest against the workpiece with a force proportioned to and opposite to the force exerted by the grinding wheel against the work.

With these and other objects in view as may hereinafter appear, the several features of the invention consist in the devices, combinations and arrangement of parts hereinafter described and claimed, which together with the advantages to be obtained thereby, will be readily apparent to one skilled in the art from the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a somewhat fgragmentary view of a cylindrical grinding machine in side elevation with parts broken away and sectioned illustrating a now preferred embodiment of the invention;

FIG. 2 is a view in side elevation on an enlarged scale of the work back rest assembly shown in FIG. 1;

FIG. 3 is a plan view of the back rest assembly shown in FIG. 2;

FIG. 4 is a diagrammatic view of the signal controlled apparatus for controlling the work back rest of a cylindrical grinding machine to exert a balancing counter-force against the work; and

FIG. 5 is an electrical diagram of the amplifier unit employed for amplifying each of the grinding wheel force and back rest counter force measuring signals.

The invention is herein disclosed in a preferred form as embodied in a cylindrical grinding machine of the general type comprising a grinding wheel and spindle rotatably supported on a slide support, movable with relation to a workpiece rotatably supported on centers on a transversely movable work support. The workpiece is further supported against the force exterted by the grinding wheel during a grinding operation by means of a back rest which may be engaged against the opposite side of the workpiece to resist the thrust of the grinding wheel.

Referring more particularly to the drawings, a grinding machine is shown comprising a base **20** having mounted thereon a longitudinally movable work support **22** and a grinding wheel slide **24** movable in a forward and back direction with relation to a cylindrical workpiece, for example, the workpiece **26**, supported between a headstock center **28** and a footstock center **30** carried on the work support **22** (see FIG. 4). The workpiece **26** is connected by means of a head stock drive pin **32** and work drive dog **34** to be driven from a motor **36** through connections not shown since this mechanism is well known and forms specifically no part of the present invention.

The grinding wheel assembly of the machine comprises a grinding wheel **38** and its supporting spindle **40** which

is mounted in bearings generally indicated at 42 (see FIG. 4) having opposed hydrostatic fluid bearing pockets which provide fluid cushions or pads for the rotating spindle, two such opposed hydrostatic fluid bearing pockets 43 and 44 being specificially illustrated. The grinding wheel 38 and spindle 40 are continuously driven from a motor 46 mounted on the grinding wheel slide 24 through connections which comprise a drive belt 48 passing around a motor pulley 50 and a pulley 52 attached to the grinding wheel spindle 40. In the illustrated construction the grinding wheel assembly is moved manually to engage the grinding wheel 38 against a workpiece 26 by means of a hand wheel 56 supported with relation to a drive shaft 58 rotatably mounted in bearings 60 and 62 in the machine base 20. The shaft 58 is connected by gears 64 and 66 with a screw 68 which is threaded into a nut 70 connected to the wheel slide 24. The screw 68 is supported to rotate and is fixed against endwise movement in bearings 72 and 74 in the base 20. The handwheel 56, which is rotatably supported on drive shaft 58, is adjustably connected to turn therewith by connections which include a gear 76 keyed to shaft 58 and a pinion 78 carried on handwheel 56 for engagement with said gear 76. In accordance with a usual grinding machine operating procedure, the handwheel 56 and shaft 58 connected thereto are turned counter-clockwise to bring the grinding wheel forward against the work, and the feed of the grinding wheel is thereafter continued, so that the wheel removes stock until a stop dog (not shown) on the handwheel engages the size stop 80 which controls the finish size of the work.

The grinding wheel handwheel 56 also operates a grind-load switch 82 hereinafter to be more fully described. For the retracted position of the grinding wheel 38 and slide 24 illustrated in FIG. 1 the cam actuator 84 at the bottom of the handwheel presses the grind-load limit switch 82 to the load position. When the cam actuator 84 leaves the limit switch upon rotation of the handwheel to advance the grinding wheel, the switch goes to the grind position and the work supporting back rest hereinafter described moves against the work.

The signal controlled back rest counter-force balancing device which forms more particularly the subject matter of the present invention comprises a work back rest assembly 86 (see FIGS. 2 and 3) consisting of a generally L shaped frame 88 having along one bottom edge an undercut downwardly extending lip 90 and along the opposite bottom edge clamps 92 for securing the back rest assembly to the dove-tail edge clamping surfaces 94, 96 of the work support 22. A back rest element consisting of a flat block 98 is mounted for forward and back movement with relation to the housing 88 on two reeds 100 and 102, of which the reed 100 is secured to lugs 104 on the front edge of the housing and supports the front end of the block 98, and the second reed 102 is connected between the upward extension of the L shaped frame 88 and the rear end of the block 98. A cover plate 106 adjustably secured to the block 98 by means of a clamping bolt 108 carries at its forward end two spaced apart downward extensions 110 and 112 between which is mounted a rocker support 114 for two work piece engaging rolls 116, 118. The rocker support is mounted intermediate its length on a pivot pin 120, and is formed above and below this pivot point with two semi-circular pockets 122 to receive the respective rolls 116 and 118. It will be noted that the path of movement of the back rest element comprising the block 98 and cover plate 106 slopes upwardly in a plane passing through the rotational work axis along the line of thrust of the grinding wheel which is the resultant of radial and tangential forces exerted by the grinding wheel. The support rolls are located, one above and one below this plane.

The back rest element is advanced from a normally retracted disengaged work loading position, as shown in FIGS. 2 and 3 by means of hydraulically operated connections which comprise a bellows type operator including a bellows 126 with a recessed cap 128 into which is fitted a short plunger 130 connected at its upper end with the lateral extension of an elbow shaped lever 132 which is mounted on a transverse pivot 134 on the back rest frame 88. The lever 132 extends upwardly adjacent the rear face of the reed 100, and with the lateral extension thereof overlying the bellows type operator comprising the bellows 126 and cap 128. When the bellows 126 and cap 128 are extended upwardly the lever 132 is rocked clockwise from the position shown in FIG. 2 to engage and to advance the back rest unit against the work.

Oil under pressure is supplied to the bellows 126 through supply connections which include an oil reservoir 136 from which oil is drawn by a pump 138 and conduit 140 at supply pressure to the hydrostatic pressure pockets 43, 44, and to a servo-valve 142, and thence through conduit 144 to the bellows 126. The servo-valve 142, diagrammatically shown in FIG. 4 consists of a valve housing 145 within which is supported a valve stem 146 having two disc shaped spools 148 and 150 and an intervening land 152. Upward movement of the valve stem 146 opens the pressure conduit 140 to the land 152 past spool 148 and admits fluid under pressure to the conduit 144 and to the bellows 126. An exhaust conduit 154 from the valve housing is shut off by spool 150. Downward movement of the valve stem 146 causes the spool 148 to shut off the supply conduit 140 and opens a connection to exhaust conduit 154. Operation of the valve stem 146 is controlled by two oppositely oriented magnets 158 and 160 and an armature 162 mounted to turn on a pivot 164 and connected at its other end to the valve stem 146. Whenever the grinding wheel 38 is engaged against a workpiece, exerting force thereon, a signal in the form of an electric current is transmitted to a wire coil 166 on the armature 162 in a direction to move the armature clockwise, moving the valve stem and spool 148 upwardly to supply oil under pressure to the bellows 126, and to move the back rest element 98 against the work. A signalled indication of any force exerted against the workpiece by the back rest element 98 is similarly provided in the form of an electric current which passes in reverse direction around a second wire coil 168 on the armature 162, biasing the armature in a counter-clockwise direction which will offset the effect of the grinding wheel force generated signal.

In the illustrated form of the invention, an extremely sensitive and accurate signalled indication is provided of any force which may be brought to bear against a workpiece when the grinding wheel comes into grinding contact therewith, by means of a differential hydrostatic pocket pressure sensing device, which acts, in combination with suitable signal amplifying devices, to detect and signal instantly any variation in the loading of the hydrostatically supported grinding wheel spindle. The pressure differential in the hydrostatic spindle bearing pockets 43, 44 induced by the loading of the grinding wheel against the workpiece is picked up by a hydraulic-electrical transducer 170, the electrical signal is substantially amplified in an electrical amplifier 172, and the amplified signal is fed to the armature coil 166 of the servo-valve 142 above referred to. The transducer 170 consists of an armature 173 connected by means of a reed 174 to swing about a fixed pivot 176. The armature is biased in one direction by a bellows 178 to which fluid under pressure is supplied by a fluid pressure sensing conduit 180 connected with the hydrostatic pocket 43, and in the opposite direction by a bellows 182 connected by a fluid pressure sensing conduit 184 with the hydrostatic pocket 44.

Any movement transmitted to the armature 173 of the differential pressure sensing device illustrated in FIG. 4 is picked up electrically by a pair of transducer coils 186, 188 mounted on E-cores 190, 192 located at opposite sides of a metallically coated portion of the armature 173, and a voltage dividing network consisting of resistances R1 and R3 on which there is impressed a voltage which may be in the order of 3.5 volts supplied by wires 194, 196

from the secondary of a transformer forming part of a conventional amplifier generally indicated at **172** and hereafter more fully described in connection with FIG. 5 of the drawings. The resistances R1 and R3 are connected to ground by a wire G. Any movement of the transducer armature **173** toward one or the other of said E-cores **190, 192** causes a voltage output to appear between the ground wire G and the junction I between the transducer coils **186, 188**. This output voltage is carried to gain control R**140**, and the adjustable portion of this output voltage is picked off and applied to the input line **202** of the amplifier **172**, the amplified output from which is transmitted through connections **204, 206** through a visual meter **208** having a pointer **210** which indicates both the direction and extent of the movement impressed on the armature **173** by the differential pressure sensing device above described. The wires **204, 206** are also connected through a grind-load switch **82** with the armature coil **166** of the servo-valve controller.

FIG. 5 is a schematic diagram of the electronic amplifier unit **172**. The device is powered by a well regulated direct current source represented by a battery **211** having a connection **213** with the primary TIP of a transformer TI.

Transistors Q3 and Q4 form an oscillator **214** which generates about 6 volts alternating voltage in the transformer primary TIP.

The oscillator transformer primary TIP directly supplies a reference voltage to a ring connected demodulator bridge **215**.

The oscillator transformer secondary winding TIS supplies about 3.5 volts excitation through connections **194, 196** across the two transducer coils **186** and **188** and also to the voltage dividing network R1, R3.

As the transducer armature **173** is moved between the two E-cores a voltage output appears between the ground point G and the junction I, between coils **186** and **188**. This output voltage is applied through the coupling capacitor C to a conventional audio frequency amplifier comprising transistors Q1 and Q2 which strengthens the signal and through transformer T2 applies the amplified signal to the demodulator bridge **215**. The demodulated output is fed to the meter **208**.

The visual indicating meter **208** for the amplifier **172** may be arbitrarily adjusted to a zero setting when the grinding wheel and spindle **40** are idling by a manual adjustment of the no load position of the transducer armature **173** relative to the E cores **190, 192**. As shown in FIG. 4 the bellows **182** is seated against an adjustable setscrew **217** which is adjusted to move the bellows **182** toward or away from the bellows **178**.

A signalled indication is provided of the hydraulic pressure built up in the bellows **126**, which is proportional to the counter-force exerted by the back rest rolls **116, 118** against a workpiece **26**, and is well adapted to be continuously compared with the signalled indication of the force exerted by the grinding wheel against the workpiece to control the operation of the servo-valve **142**, so that the back rest will exert a continuously balancing counter-force against the rotating workpiece. The hydraulic pressure in the back rest actuating bellows **126** is picked up by a hydraulic-electrical transducer **216**, the electrical signal produced being amplified by an amplifier **218** and fed to the armature coil **168** of the servo-valve **142**. The transducer consists of an armature **220** connected by means of a reed **222** to swing about a fixed pivot **224**. The armature **220** is biased in one direction by a bellows **226** to which fluid pressure is supplied by a fluid pressure sensing conduit **228** connected with the bellows **126**, and in the opposite direction by means of a coiled spring **230** seated against an adjusting screw **232**. A pair of transducer coils **234** and **236** mounted on E-cores **238, 240** located at opposite sides of the armature are connected through a voltage dividing network including resistances R1*a* and R3*a* and a gain control including resistance R**140***a* to the amplifier **218** and a visual meter **244**, which parts are exact duplicates of the voltage net work, gain control, amplifier **172** and visual meter **208** above described. Output connections **246** and **248** from the amplifier **218** and visual meter **244** are connected through the grind-load switch **82** with the armature coil **168** of the servo-valve controller.

The illustrated signal controlled apparatus for actuating the back rest of a cylindrical grinding machine to exert a counter-force against the work which will balance the force of the grinding wheel operates in the following manner:

Transducer **170** yields an electrical signal which is proportional to the force of the grinding wheel **38** against the work. This signal is sent to the servo-valve **142** via amplifier **172**, and operates the valve in such a way as to open the pressure line to the work back rest bellows **126**. Transducer **216** yields an electrical signal which is proportional to the counter-force exerted by the work back rest rollers **116** and **118** against the workpiece. This signal, via amplifier **218**, closes the pressure line **140, 144** to the work support bellows **126**. When the electrical signals from each transducer are now balanced, the force on the workpiece from the grinding wheel **38** will be balanced by the force of the work support.

Initially, with the grinding wheel spindle idling, the amplifier **172** is adjusted to give a zero reading on its meter **208** indicating a zero signal. Next, the work back rest **98** is moved forwardly, so that the work engaging rollers **116, 118** make light contact with the workpiece by an adjustment of the work back rest bellows counter-force indicating transducer **216**. This adjustment is effected by means of the adjusting screw **232**, which adjusts the effective strength of spring **230** against the back rest bellows **126** pressure sensing conduit **228** and bellows **226**. Gain control R**140***a* is now adjusted to provide a zero reading of meter **244**. These adjustments establish a nominally zero force between the back rest **98** including rollers **116, 118** and the workpiece, and between the grinding wheel **38** and workpiece for this idle condition.

As the grinding wheel now moves against the work, a differential oil pressure is set up in the wheel spindle bearing pockets **43, 44** proportional to the force of the wheel against the workpiece. This differential pressure, is transmitted to the bellows **178, 182** of transducer **170**. This differential causes the armature **173** to move which upsets the balance between the coils **186, 188** generating an electric signal. It is this signal which is passed on to amplifier **172**, and then to the servo-valve **142**, causing the winding **166** to be energized opening the servo-valve fluid power connection to the back rest bellows **126**. The back rest rollers **116, 118** are pressed against the workpiece exerting a counter-force which tends to exceed the force exerted by the grinding wheel. The pressure rise within the back rest bellows **126** causes the armature **220** of transducer **216** to move against the pressure of spring **230** upsetting the electrical balance in the coils **234, 236** to produce an electrical signal which is amplified and applied to energize armature coil **168** tending to shift the servo-valve **142** to its closed position.

From the foregoing, it will be evident that the signals from the two amplifiers are proportionate in strength to the force and counter-force exerted respectively by the grinding wheel **38** and back rest rollers **116, 118** against the workpiece, and further that these opposed signals acting upon the armature controller **162** of the servo-valve **142** will tend to produce a stabilized relationship between the force and counter-force directed against the workpiece with the illustrated construction it is necessary only to balance the signals produced by the two amplifiers **172** and **218** in order to bring these forces into exact balance as, for example, by an adjustment of the gain controls R**140** and R**140***a* of the respective amplifiers. The gain control of the amplifier **172** is set at a convenient point to have as much response as practicable without instability. The gain control R**140** is now manipulated to

balance the two signals so that a dial indicator **250** located near the point of grinding shows no deflection of the work.

When the grinding wheel is moved away from the workpiece at the finish of the grinding process, as for example, by the return of the hand wheel **56** to the initial load position, the dog **84** on the hand wheel will return the work-load switch **82** to its load or off position so that the load bias **252** causes the servo-valve **142** to close its pressure port and open its tank port. Oil pressure will now be removed from the back rest bellows **126** enabling the back rest rollers **116, 118** to back away from the workpiece also.

It will be understood that while a presently preferred embodiment of the invention is here shown comprising a device for sensing and for signalling an unbalance in the pressure pockets of a hydrostatic spindle bearing produced by variations in the force of grinding, and including valve means controlled by the signalled unbalance offset by a signalled back rest applied pressure for applying a controlled hydraulic pressure against the back rest to move said back rest against the workpiece with an equal and opposite counter-force, the invention in its broader aspects envisions the use of any suitable strain sensing device adapted to produce a signal proportionate to said applied grinding force, and a suitable control device which may well include suitable hydraulic valve mechanism actuated by an amplified signal of any such strain for controlling the pressure applied to cause the back rest to exert a counter-force equal and opposite to the force of the grinding against the work.

The invention having been described what is claimed is:

1. A counter-force motivated back rest for a cylindrical grinding machine, having a grinding wheel assembly including a grinding wheel, a grinding wheel support and power means for driving said grinding wheel, a rotatable work support and means for relatively moving said supports to advance the grinding wheel relative to the work support, having in combination, a support on which the back rest is movable toward the work support in a direction opposed to the force of the grinding wheel, means for applying pressure to force said back rest toward the work support, a device for sensing and for signalling variable unbalance producing loading stresses within said grinding wheel assembly during said advance of the grinding wheel, and a control device for controlling the pressure exerted against the back rest responsive to said signalled unbalance producing loading stresses for regulating said back rest applied pressure to apply a counter-force against the force of the grinding wheel proportionate to said unbalance producing loading stresses within said grinding wheel assembly.

2. The combination of claim **1** in which said control device comprises a valve mechanism operable for controlling the pressure applied to said back rest, and a device actuated by the signalled unbalance producing loading stress within said grinding wheel assembly for operating said valve mechanism to apply a counter-force through said back rest proportionate to said signalled unbalance producing loading stress.

3. The combination of claim **1** in which there is provided means for sensing and for signalling variable pressures applied to said back rest, a device for varying said applied pressure, and in which said control device comprises means actuated by said signalled grinding wheel unbalance producing loading stress to increase said applied pressure, and by a back rest applied pressure originated signal to decrease said applied pressure, thereby to proportion said back rest applied pressure to said grinding wheel loading stress.

4. The combination of claim **3** for a grinding machine provided with hydrostatic spindle bearings including opposed hydrostatic pressure pockets, which comprises a device to sense and to signal any unbalance of pressure in said opposed hydrostatic pressure pockets corresponding with the work engaging force of the grinding wheel, means for applying hydraulic pressure to force the back rest in a direction opposed to the force of the grinding wheel, a signalling device for signalling the level of said back rest applied hydraulic pressure, and a servo-valve for controlling the supply of hydraulic pressure to the back rest, including a device controlled by a signalled increase of unbalance of pressure in said opposed hydrostatic pressure pockets to open said valve and by a signalled increase in the level of said back rest applied hydraulic pressure to close said valve, thereby moving said valve control valve to a position in which said signals are in balance.

5. The combination of calim **4** in which said device for signalling any unbalance of pressure in said opposed hydrostatic pressure pockets comprises a hydraulic-electrical transducer and an electrical signal amplifying device, said device for signalling the level of said back rest applied hydraulic pressure comprises a hydraulic-electrical transducer and an electrical signal amplifying device, and said servo-valve comprises a valve controller connected to be urged in opposite directions between open and shut-off positions by said respective amplified electrical signals.

6. The combination of claim **5** in which each said electrical amplifying device includes a visual signal strength indicating means providing zero, plus-and-minus readings and a gain control device adjustable to obtain an adjusted zero reading of said visual indicating means, for an unstressed grinding wheel idling position.

7. In a cylindrical grinding machine, having a grinding wheel assembly including a grinding wheel, a grinding wheel spindle, hydrostatic bearings including opposed hydrostatic fluid pressure pockets for said spindle, a grinding wheel support, and power means for driving said grinding wheel spindle, a work support including a rotative work holder, and means relatively positioning said supports for grinding, the combination of a work back rest movable in a direction opposed to the positioning movement of the grinding wheel, means applying a force to press the back rest in said direction opposed to the grinding wheel, and a signal controlled back rest counter-force balancing device which comprises a signalling device connected with said opposed hydrostatic fluid pressure pockets to detect and signal any unbalance of pressure in said hydrostatic bearing induced by the work engaging force of the grinding wheel and a control device for controlling the pressure exerted against the back rest responsive to any unbalance of pressure in said hydrostatic bearings for regulating said back rest applied pressure to apply a counter-force proportionate to said pressure unbalance in said hydrostatic bearings.

8. The combination of claim **7** which includes an unbalance sensitive hydrostatic fluid pressure pocket signal producing transducer and amplifier, means for applying hydraulic pressure to force the back rest in said direction opposed to the grinding wheel, a back rest hydraulic pressure sensitive signal producing transducer and amplifier, a back rest pressure control valve, and a valve operator acted upon by a hydrostatic fluid pressure pocket unbalance signal to open said valve, and by a said back rest pressure to close said valve thereby to produce a balance position of said valve operator and valve controlled thereby.

9. The combination of claim **8** in which said back rest hydraulic pressure sensitive signal producing transducer comprises an armature, a hydraulic pressure sensing device acting upon said armature in one direction, and means exerting pressure upon said armature in the opposite direction adjustable to initially position the back rest in an idling light work contact position.

10. The combination of claim **9**, in which means are provided for amplifying each of said signals including means to adjust the amplification of one said signal rela-

tively to the other said signal to provide a counter balancing force of said back rest equal and opposite to the force of the grinding wheel.

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