

[54] GRINDING METHOD AND APPARATUS

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[58] Field of Search 51/33 R, 48 R, 49, 50, 92 R,
51/95 R, 95 WH, 356, 267, 322, 281

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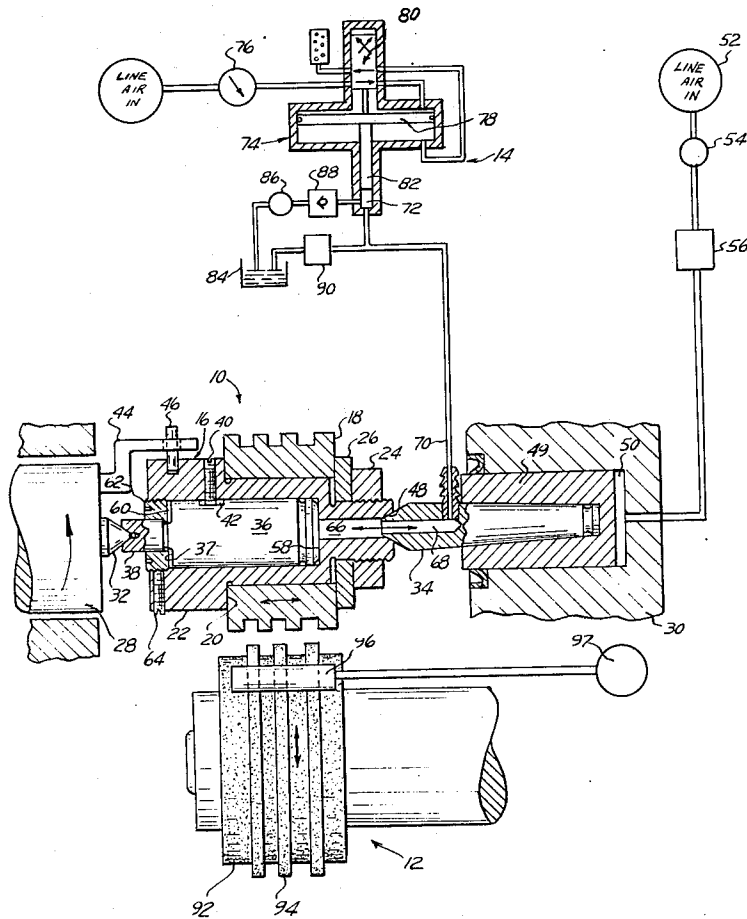
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[57] ABSTRACT

A method and apparatus for grinding involving limited transverse reciprocation of the grinding wheel relative to the workpiece during the grinding operation to allow coolant to reach the grinding zone during deep form grinding and/or to improve the surface finish. The apparatus includes a first embodiment in which cyclical hydraulic pressure is used to continuously reciprocate a workholder against a pneumatic clamping bias in a direction transverse to the grinding action and parallel to the axis of rotation of the grinding wheel simultaneously with the grinding operation.

In a second embodiment, an internally ground workpiece is similarly reciprocated by cyclically controlling fluid flow to opposed portions of a structure which is hydraulically positioned by the fluid flow and which serves to axially locate the workholder with respect to its workhead.

24 Claims, 5 Drawing Figures



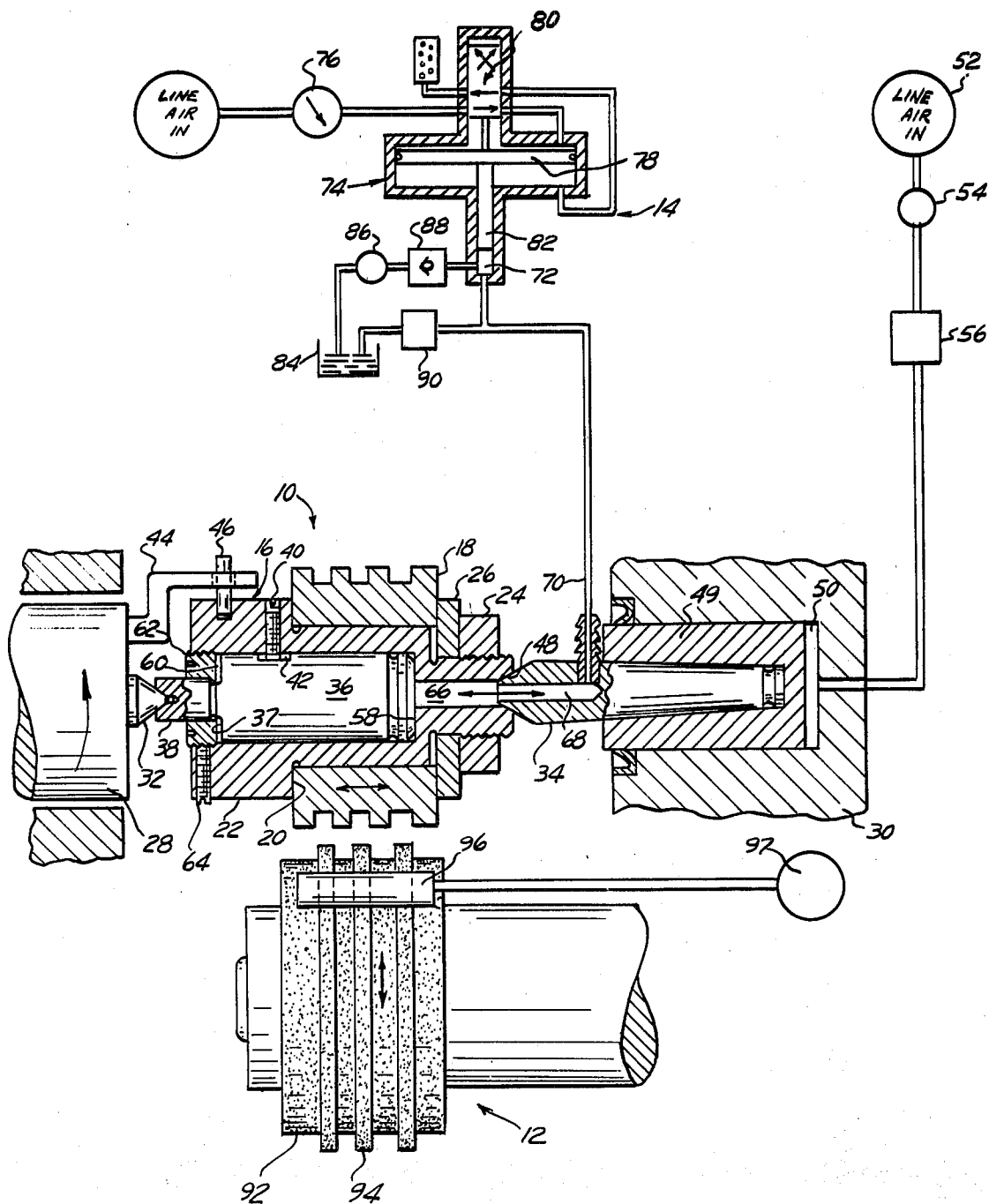
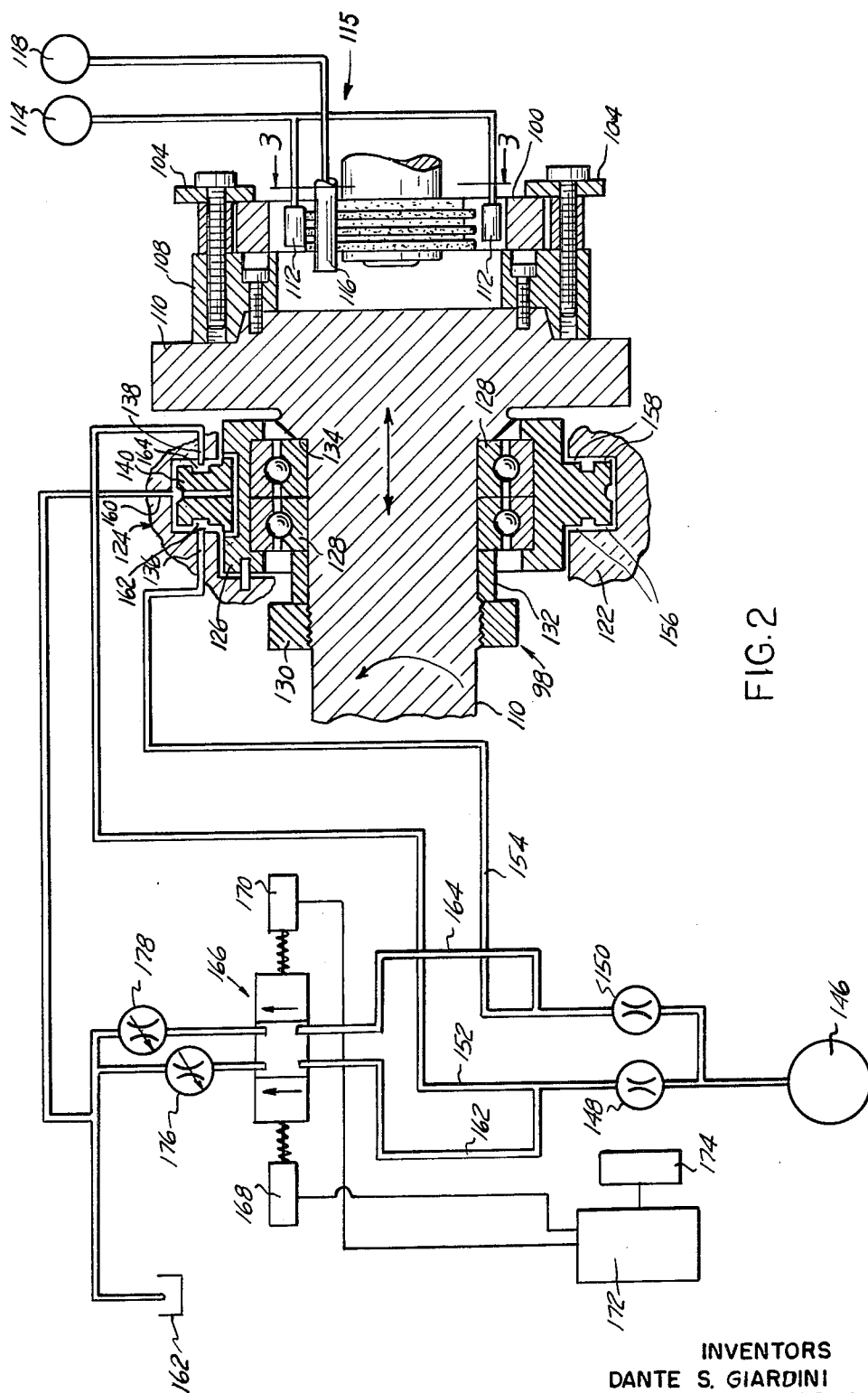


FIG. 1

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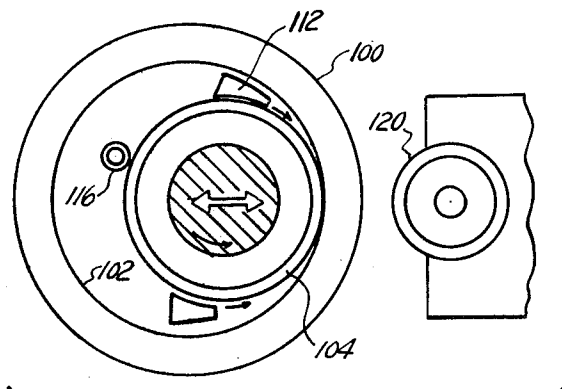


FIG. 3

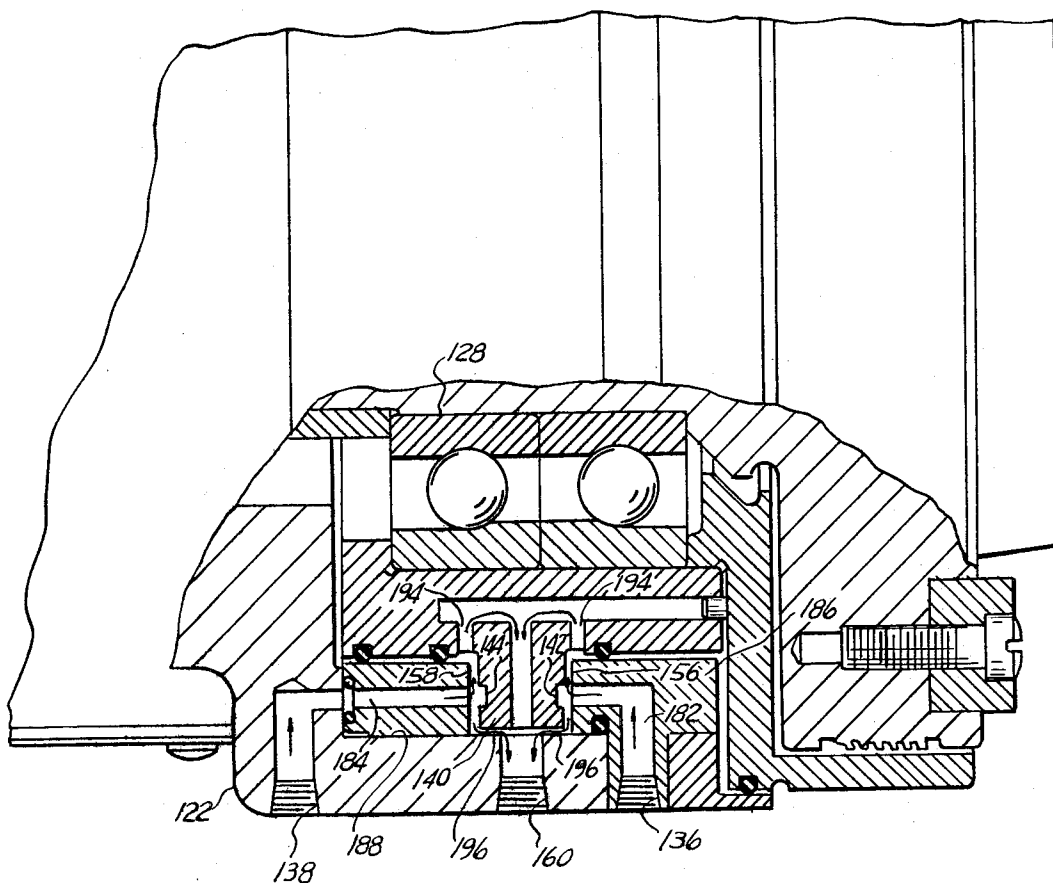
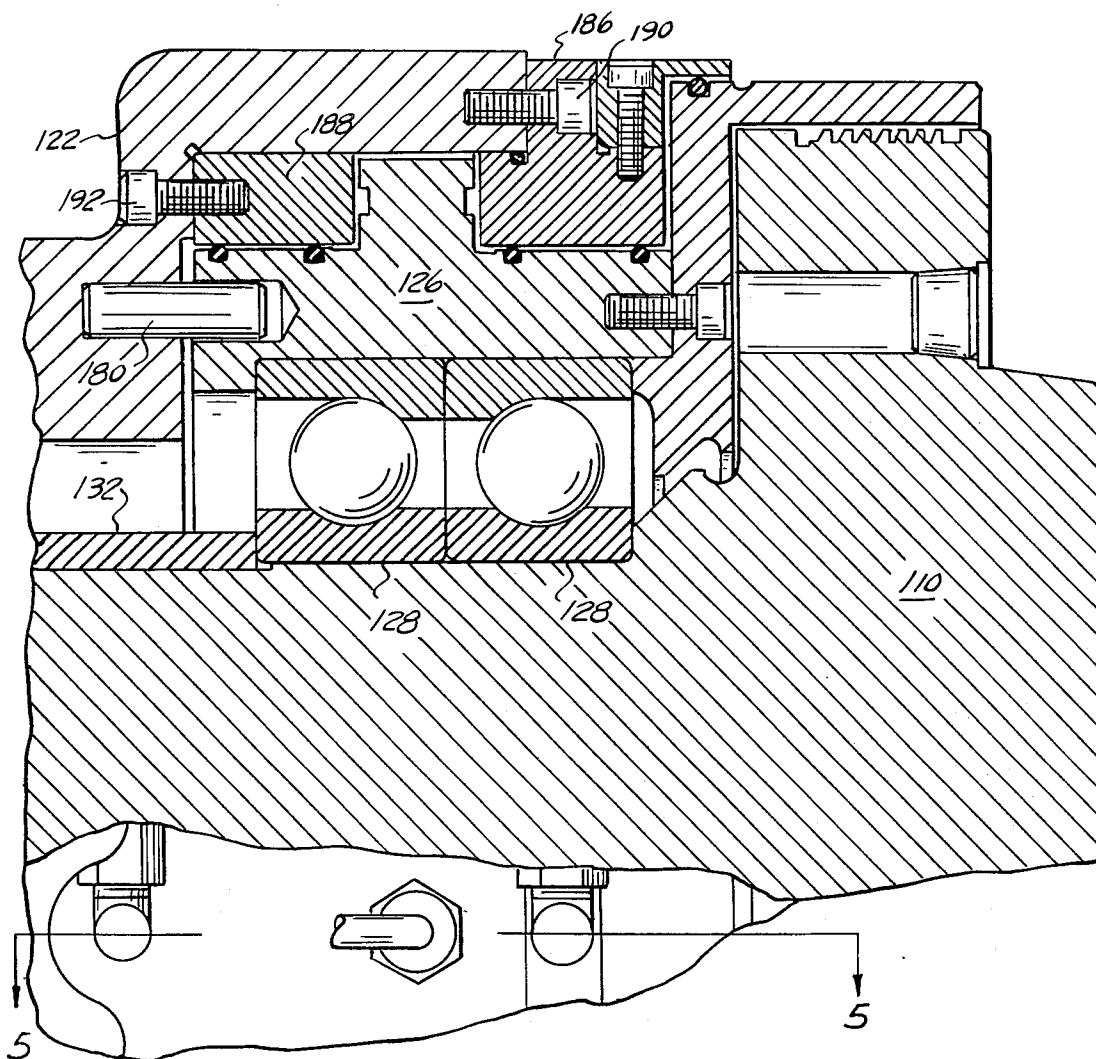


FIG. 5

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GRINDING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

The practice of form grinding in which the grinding wheel is contoured in the complementary pattern of the contour of the finished part, has presented special problems when the form includes relatively deep and narrow contour portions, since coolant and lubricants are prevented from reaching the grinding zone, which in turn severely limits material removal rates as well as adversely affecting surface finishes, and leading to side burn and taper problems, as well as excessive heat build-up in the workpiece.

This effect is severely aggravated when attempts are made to grind internal surfaces with external grinding surfaces, since the area of the grind zone is greatly increased by the extent of tangency between the grinding wheel and the workpiece, aggravating the coolant and lubricant starvation problem and creating the problem of severe wheel loading or fouling with the ground material.

In addition, this basic problem has led in some circumstances to thermally induced contraction of the outer portions of the workpiece onto the grinding wheel form during the deepest penetration thereof which can produce an undesired chamfering of the form by the abrading effect of the grinding wheel on the workpiece portions tending to grip it as a result of this contraction, particularly upon withdrawal.

Therefore, it is an object of the present invention to provide a method and apparatus for grinding which will allow the flow of coolant to reach the grinding zone during deep form grinding and will maintain the work at an acceptable temperature.

It is a further object to provide such a process which will improve the surface finish of the ground part.

SUMMARY OF THE INVENTION

These and other objects which will become apparent upon a reading of the following specification and claims are accomplished by slightly and continuously reciprocating the workpiece relative to the wheel in a direction transverse to the grinding activity to thereby allow coolant to reach the grind zone via the side clearance created and to improve the surface finish by the slight cross grinding resulting therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view in partial section of a workholder and grinder arrangement according to the present invention for an external grinder together with a schematic representation of the control system associated therewith.

FIG. 2 is a schematic representation of a workhead and grinder arrangement according to the present invention for an internal grinder together with the associated control system.

FIG. 3 is a sectional view taken along line 3—3 in FIG. 2.

FIG. 4 is a partial sectional view of the workhead depicted schematically in FIG. 2.

FIG. 5 is a view of the section taken along the line 5—5 in FIG. 4.

DETAILED DESCRIPTION

In the following detailed description specific embodiments will be described in order to provide a complete understanding of the invention and certain specific terminology will be employed for the sake of clarity, but it is to be understood that the invention is not so limited and may be practiced in a variety of forms and embodiments.

Referring to the drawings and particularly FIG. 1, a workholder assembly 10 and form grinding wheelhead 12 are partially depicted, together with a control system 14.

The workholder assembly 10 includes an arbor 16 which serves to clamp the workpiece 18 against a shoulder 20 on arbor member 22 by means of a nut 24 and washer 26.

The arbor assembly 16 is supported with respect to the workhead between a work drive spindle 28 and a tailstock center housing 30 by means of a workhead center 32 and a tailstock center 34.

The workhead center 32 is secured or integral with the work drive spindle 28, supports the arbor member 22 via a piston member 36 slidably disposed therein and having a cooperating taper end 38. The piston member 36 is rotatably secured to the arbor member 22 by means of a screw member 40 received into a groove 42 in piston member 36.

A driving connection between the drive spindle 28, which is driven by the workhead drive motor (not shown) and the arbor member 22 is provided by a drive dog affixed to the drive spindle 28 and cooperating with a drive pin 46 carried by the arbor member 22.

The tailstock center 34 is slidably disposed in the housing 30 affixed to the workhead, and cooperates with a taper surface 48 on the other end of the arbor member to rotatably support the arbor assembly 16 and attached workpiece.

The tailstock 34 is carried by a tailstock air piston 49 biased to the left in the housing 30 as viewed in FIG. 1 by means of air pressure applied in the cavity 50 via a fluid connection with a source of air pressure 52, a regulator 54, and control valve 56 by which the air pressure may be cut off and relieved from the cavity 50. Hence, when the air pressure is allowed in cavity 50, the arbor assembly 16 is tended to be clamped between work center 32 and tailstock center 34 by means of the piston member 36 abutting against a shoulder 58 formed in the arbor member 22.

The piston member 36 is provided with an axial clearance space 60 in the arbor member 22 which may be adjusted by means of a nut 62 threadedly received therein and a cooperating set screw 64.

Hence, a lost motion connection is created between the arbor assembly 16 and the tailstock and workhead center 34, 32.

Communicating with the piston member 36 is an axial fluid passage 66 formed in the arbor member 22 which is aligned with a fluid passage 68 formed in the tailstock center 34, in turn communicating with a fluid line 70.

Fluid line 70 communicates with a pumping chamber 72 of an air operated pumping unit 74. This unit and suitable equivalents are commercially available and hence a detailed description is not felt to be necessary here.

Suffice it to say that line air supplied via a flow control valve 76 is alternately applied to the opposite sides of a power piston 78 by means of an air control valve 80 to cause reciprocation of a pumping piston 82 in the pumping chamber 72, of a frequency determined by the flow rate set by the flow control valve 76.

The pumping chamber 72 also communicates with a liquid reservoir 84, which could be the coolant supply via filter 86 and check valve 88, while the line 70 also communicates with the reservoir via pressure relief valve 90.

Hence, during the upward stroke of the piston 82, coolant is drawn into the pumping chamber from the reservoir 84 and line 70 and during the downward stroke coolant is forced into line 70, since backflow is prevented by the check valve 88, causing hydraulic pressure reacting against the piston 36 to force the arbor member 22 to the right together with tailstock center 34 and tailstock air piston 49 against the bias of the air pressure in cavity 50, carrying the workpiece with it. Upon contact of the piston end 37 with the nut 62, the hydraulic forces are cancelled out and movement of the arbor member 22 ceases. At this point, if the pumping piston 82 continues to move downwardly, the adjustable relief valve 90 opens and allows the additional coolant to be displaced back into the reservoir 84.

Upon return movement of the pumping piston 82 upwardly the bias pressure in cavity 50 is reasserted on the housing 30, tailstock center 34, and arbor member 22 to cause them to move to the left and recreate the clearance space 62. Hence, the workpiece 18 is reciprocated in a direction transverse to the feeding and grinding at a frequency determined by the setting of the flow control valve 76 and with a stroke determined by the adjustment of the nut 62 in the arbor member 22.

The grinding head 12 includes a grinding wheel 92 which has its periphery 94 shaped into the form to be ground into the workpiece 18. This form will be slightly undersized to compensate for the workpiece reciprocation.

An abrading member such as grinding wheel 92 is rotated by means of a conventional grinding wheel drive mechanism (not shown) with the grind head mounted so as to be advanced into the workpiece 18 during the grinding operation.

A dressing mechanism (not shown) such as crush rollers is used to periodically dress the wheel periphery in the conventional manner, and coolant and nozzle 96 and supply 97. A jet wheel cleaner arrangement may also be provided.

In use, the workpiece 18 is clamped to the arbor member 22 by the nut 24 and washer 26, and the assembly 16 is then placed between the headstock and tailstock centers 32, 34 aligning the drive dog 44 with the drive pin 46.

Bias air pressure is then supplied to cavity 50 by means of control valve 56 to securely retain the assembly between these centers.

The flow control valve 76 is then adjusted to create a reciprocation of the assembly 16 at a frequency determined by the feed rate to be used, i.e., a relatively rapid reciprocation rate will be necessary at relatively rapid feed rates to enable coolant to flow through the side clearances to reach the grinding zone during each stroke. This has been found to require, for typical applications, one stroke for each infeed increment of 0.003 to 0.004 inch. For example, an infeed rate of 0.060 inch per minute calls for a frequency of 15 to 20 cpm.

Similarly, the stroke length will be determined by the relative depth of the cut, i.e., a relatively long stroke will be required for forms which are relatively deep with respect to their width to allow the coolant to penetrate to the bottom of the form. This will vary, for typical applications, from 0.001 inch stroke up to 0.030 inch for very deep forms.

The drive motors are then engaged to drive the workpiece 18 and grinding wheel 92, the grinding wheel 92 then being advanced into the workpiece 18 while it is being continuously reciprocated transversely to both the grinding and feeding relative movement to perform the form grinding operation.

The improved cooling and lubricating allowed by the side clearances thus created has resulted in numerous improvements over conventional grinding processes: increases stock removal rates; finishes have been improved partly due to the slight cross grinding which results from the reciprocation; increased crush tool life due to the decreased dressing cycles required; side burn which formerly occurred as a result of coolant and lubricant starvation has been minimized; heat generation has been reached, with the relative share of heat absorbed by the workpiece also reduced. Side form taper has also been lessened due to more even wear of the grinding wheel form contour.

It should be noted that surface finishes will also be improved in nonform grinding situations since the cross movement produces an improved finish when a coarse wheel is being used.

Referring to FIGS. 2-4, an internal form grinding arrangement is shown which utilizes the work reciprocation principle according to the present invention.

In this embodiment, workhead assembly 98 is mounted for reciprocal movement as indicated to position a workpiece 100 to be ground on an internal surface 102 (FIG. 5) opposite a grinding wheel 104. The workpiece 100 is clamped at a plurality of points 106 to a spacer ring 108 which is in turn secured to a workholder shaft 110.

The grinding wheel 104 is mounted for high speed rotation on a wheelhead assembly (not shown) and to be advanced into the workpiece 100 in the conventional manner to create the grinding action.

Coolant nozzles 112 together with an associated coolant source 114 are provided as well as a jet wheel cleaner 115 including a nozzle 116 and associated high pressure source 118. The nozzle is adapted to reciprocate across the surface of the grinding wheel and apply a high pressure fluid jet thereto.

The jet wheel cleaner 115 plays a crucial role in the success of the internal form grinding process here disclosed inasmuch as it "wets" the voids in the grinding wheel and prevents chemical reaction between the workpiece and grinding wheel material by occlusion of ambient oxygen. Details of construction and operation of this unit, as well as its function in this context can be obtained by reference to U.S. Pat. No. 3,167,893 and copending patent application Ser. No. 48,355, filed June 22, 1970 entitled, "Method and Apparatus for Internal Grinding" both assigned to the assignee of the present invention.

A crush form roller 120 is provided in order to dress the grinding wheel 104 occasionally into the required form, which is accomplished by withdrawing the workhead assembly and advancing the grinding wheel 104 into the crush roller 120 and rotating it slowly until the dressing is complete in a conventional manner.

In this embodiment, the workholder shaft 110 is mounted for the reciprocal movement according to the present invention. This is accomplished by axially positioning the workholder shaft 110 in the workhead frame 122 by means of a hydraulic thrust bearing arrangement 124, which includes means for hydraulically varying the axial position of a ring member 126 which in turn positions the workholder shaft 110 by means of thrust bearings 128. The thrust bearings 128 bear axially on the ring 130 and spacer 132 and the shoulder 134 formed on the workholder shaft 110. Hence, the workholder shaft 110 is rotatably supported and axially positioned by the ring member 126.

The hydraulic positioning of the ring member 126 is accomplished by introducing high pressure hydraulic fluid at ports 136 and 138 on opposed sides of the peripheral portion 140 of the ring member 126 opposite grooves 142 and 144, respectively. The hydraulic fluid is supplied from source 146 via calibrated orifices 148 and 150, which are selected to provide an equal flow in lines 152, 154 connected to ports 136 and 138, respectively.

The fluid thus supplied passes through the clearance spaces 156 and 158 between the ring member peripheral portion 120 and collected by drain port 160 connected to the sump 162.

If the flows through each clearance space 156 and 158 are selected to be equal, hydrodynamic forces cause the ring member 126 to be centered, since the opposing sides will be acted upon equally by fluid pressure only if the pressure drops occurring across the clearance spaces 156 and 158 are the same, which will occur only for equal spacing. Thus, the ring member 126 will be shifted until centered as long as the flow rates in lines 152 and 154 are the same.

These flow rates are selectively varied with respect to each other by bleed lines 162 and 164 which tap into lines 152 and 154, respectively, downstream of the orifices 148 and 150.

Flow through each of these bleed lines 162 and 164 is controlled by four-way solenoid valve 166, which is alternately cycled by a pair of solenoids 168 and 170. A timer 172 adjustably controls the length of time of energization and deenergization of each of the solenoids. A connection with the feed limit switch 174 which limits the inward travel of the wheelhead causes both of the solenoids to be deenergized and the valve 166 to be centered in turn causing both lines 162 and 164 to be blocked. When either of solenoids 168 and 170 is energized, its associated bleed lines 162 or 164 is connected via adjustable orifices 176 and 178 with the sump 162.

Hence, a controlled amount of fluid is bled off in the associated line 152 or 154 causing a reduction in the pressure and available flow at port 136 and 138. This in turn results in an unbalance of the hydraulic forces acting in the ring member 126 due to the reduction in pressure acting on one side or other of the peripheral portion 140 of the ring member 126. Therefore, the ring member 126 will shift towards the low pressure port until the increase in pressure due to the reduction in clearance 156 or 158 coupled with the decrease in pressure due to the increase in clearance on the high pressure side offset the effect of the bleed line 162 or 164.

Thus, as the solenoids 168 and 170 are alternately energized, the ring member 126 will shift axially to and fro with a frequency determined by the timer 172 and a stroke determined by the setting of the variable orifices 176 and 178. This results in a similar movement of the workpiece 100 since the ring member axially positions the workholder shaft 110 to which the workpiece is secured.

When the grinding is complete, the deenergization of both solenoids 168 and 170 results in centering of the ring member 126 which in turn automatically centers the grinding wheel 104 in the opening ground in the workpiece 100 allowing the grinding wheel 104 to be withdrawn scoring or chamfering of the side form.

Referring to FIGS. 4 and 5, an actual workhead configuration is shown constructed according to the principle of the schematics of FIGS. 2 and 3.

In this arrangement the workholder shaft 110 is axially positioned in the workholder housing 122 by means of thrust bearing 128 seated against spacer ring 132 and shoulder 134 and cooperating with a ring member 126 in the same manner indicated schematically in FIGS. 2 and 3.

The ring member 126 is pinned at 180 to prevent rotation with the workholder shaft 110.

High pressure fluid is introduced at ports 136, 138 and passed to grooves 142 and 144 via passages 182 and 184 which are formed in rings 186 and 188, respectively. Rings 186 and 188 are secured to the housing 122 by cap screws 190 and 192.

High pressure fluid passes out of passages 182 and 184 into grooves 142 and 144, thence through clearance spaces 156 and 158 to be collected at a plurality of openings 194 communicating with corresponding openings 196 and at the outer clearance spaces 198, all communicating with the drain port 160.

As in the embodiment shown in FIG. 1, the frequency and stroke of the workpiece 100 reciprocation selected will depend on the feed rate and relative depth of the form, higher frequencies for higher feed rates, and longer strokes for relatively deeper forms. In an actual application strokes from 0.0005 to 0.005 inch produced satisfactory results.

From this description, it should be apparent that numerous advantages are obtained in grinding processes incorporating the work reciprocation action of the present invention, such as higher material removal rates, more accurate deep form grinding processes with reduced side burning and scoring. Heat build-up in the workpiece is also minimized and surface finishes improved.

In addition, while the invention has been described in the context of specific embodiments and processes, it should be understood that the invention is not so limited and may be used in numerous embodiments and processes.

What is claimed is:

1. In a machine for grinding of a workpiece of the type having an arrangement for feed advancing into each other a form grinding member substantially shaped into the form to be ground into the workpiece, and the workpiece, with means for causing adjacent surfaces of the abrading member and workpiece to be in relative motion to create the grinding action, the improvement comprising:

positioning means relatively and slightly moving said workpiece and said abrading member transversely to the grinding and feeding motion during the grinding activity.

2. The machine of claim 1 wherein said relative movement created by said positioning means is cyclical.

3. The machine of claim 2 wherein said positioning means includes means for reciprocating said abrading member and said workpiece relative each other transversely to said feed and grind motions during said grinding action.

4. The machine of claim 3 wherein said positioning means includes workholder means holding said workpiece relative to said abrading member and including an arbor member securable to said workpiece and also including means supporting said arbor member on said workholder means allowing a range

of limited movement relative thereto along the line of said transverse movement; and further including control means cyclically moving said arbor member through said range of limited movement.

5. The machine of claim 4 wherein said means supporting said arbor member includes a center member rotatably supporting said arbor and wherein said control means includes means cyclically applying fluid pressure to said arbor through said center member.

6. The machine of claim 4 wherein said control means includes means for cyclically applying fluid pressure to said arbor and also including bias means applying a force counter to said fluid pressure.

7. The machine of claim 6 wherein said means supporting said arbor member also includes a piston member slidably disposed in said arbor member along the line of said transverse movement and also includes a second center member rotatably supporting said piston member and wherein said control means applies said fluid pressure to a chamber defined at least in part by said piston member and said arbor.

8. The machine of claim 7 further including means for rotating said arbor and workpiece and also including a rotational connection between said arbor member and said piston member.

9. The machine of claim 7 further including means for adjustably limiting the movement of said piston in said arbor whereby the range of said limited movement may be adjustably varied.

10. The machine of claim 3 wherein said positioning means includes means continuously reciprocating said abrading member relative said workpiece during said grinding action.

11. The machine of claim 3 including a workholder shaft, means for securing said workpiece to said shaft, means for rotatably supporting said workholder shaft relative said abrading member including a workhead frame, and wherein said positioning means includes means for axially reciprocating said workholder shaft relative said workhead frame to cause said transverse movement.

12. The machine of claim 11 wherein said positioning means includes a member axially connected to said workholder shaft and control means alternately applying an unbalanced force in opposed directions on said member to cause said transverse movement.

13. The machine of claim 12 wherein the control means includes fluid supply means for applying unequal fluid pressures alternately to opposed portions of said member.

14. The machine of claim 13 wherein said control means includes means for equalizing said fluid pressure after axial movement of said member relative said workhead frame.

15. The machine of claim 14 wherein said control means includes an opening in said workhead frame with a portion of said member disposed therein to create clearance spaces on either side or axially of said member and said workhead frame and wherein said fluid supply means includes a source of fluid pressure and a fluid connection therewith to each clearance space.

16. The machine of claim 15 wherein said equalizing means includes means for causing said fluid to flow through said clearance spaces to a low pressure region, whereby axial shifting of said member causing an increase in clearance space on one side and decrease of the other side causes a countering increase and decrease in pressure in each of the clearance spaces to equalize the effect of the unequal pressures applied by said fluid supply means.

17. The machine of claim 16 including means for selectively adjusting the relative difference in pressure applied to said member, whereby the stroke of said reciprocal movement may be selectively adjusted.

18. The machine of claim 2 further including means for selectively adjusting the frequency of said cyclical movement.

19. An improvement in the abrading process which includes the step of relatively moving a form grinding member substantially shaped into the form to be ground into the workpiece,

and a workpiece and advancing said abrading member relative to the workpiece so as to cause an abrading action thereon, the improvement comprising:

the step of relatively and slightly moving the workpiece and abrading member transversely to the feed and abrade relative movement during said abrading action whereby a cross grind and side clearance are provided.

20. A form grinding process including the steps of:

relatively moving a workpiece and abrading member having the shape of a complementary slightly undersized form to be ground;

relatively advancing the portion of the abrading member having the form thereon and portion of the workpiece to ground into each other while continuing said relative movement to produce said grinding action;

and relatively moving said abrading member and said work-

piece during said grinding action in a direction transverse to said other relative motions through a range corresponding to the slight undersizing of the form.

21. The process of claim 20 further including the step of directing coolant into the grinding zone.

22. The process of claim 19 wherein said workpiece and form grinding member are relatively moved through a range of 0.001 to 0.030 inch.

23. The process of claim 20 wherein said workpiece and form grinding member are relatively moved through a range of 0.001 to 0.030 inch.

24. The machine of claim 1 wherein said positioning means causes relative transverse motion on the order of 0.001 to 0.030 inch.

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