Feb. 18, 1958 R. M. ARBUCKLE ET AL 2,823,492

GRINDING MACHINE AND METHOD

Filed July 16, 1954

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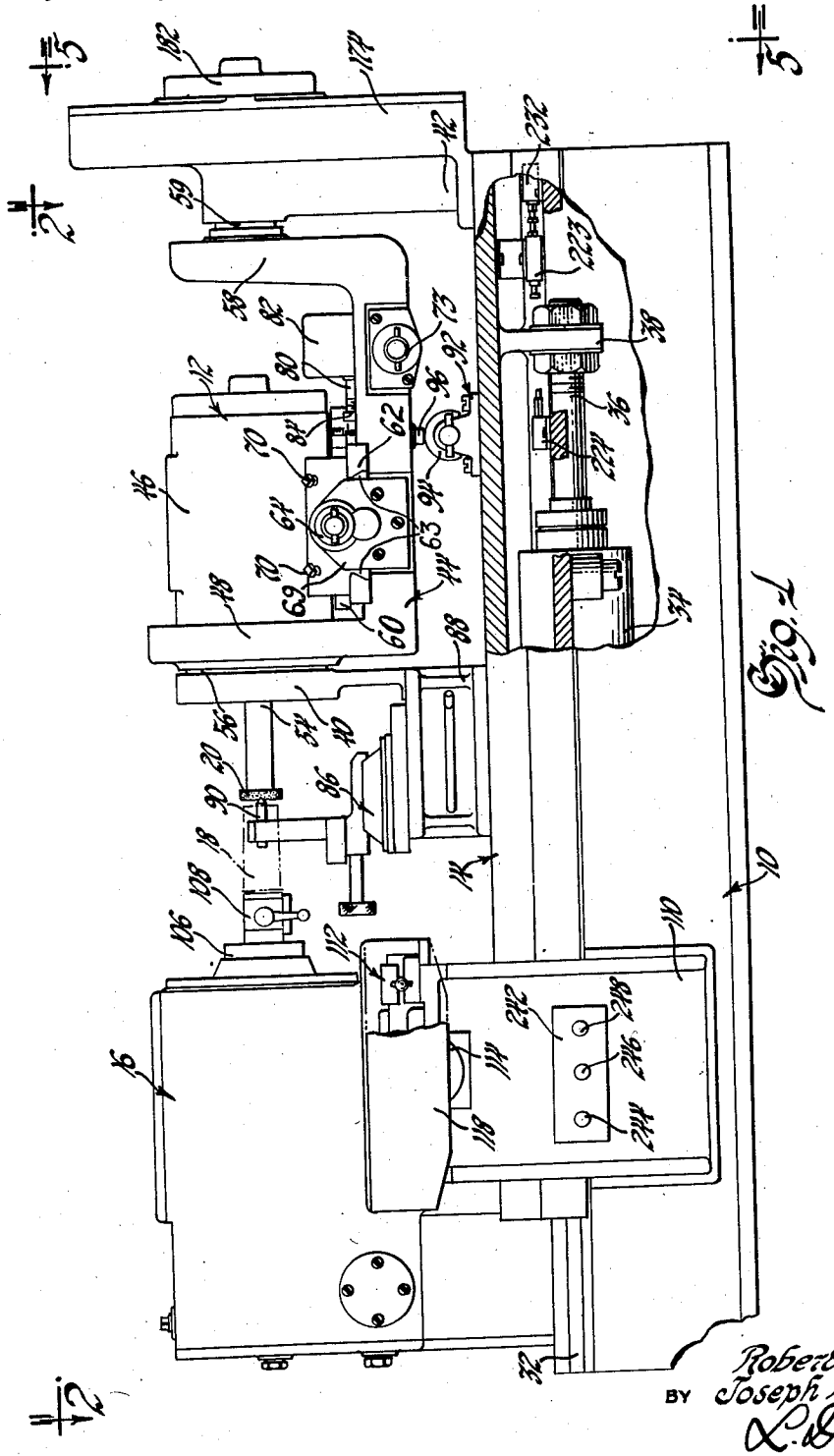


Fig. 1

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GRINDING MACHINE AND METHOD

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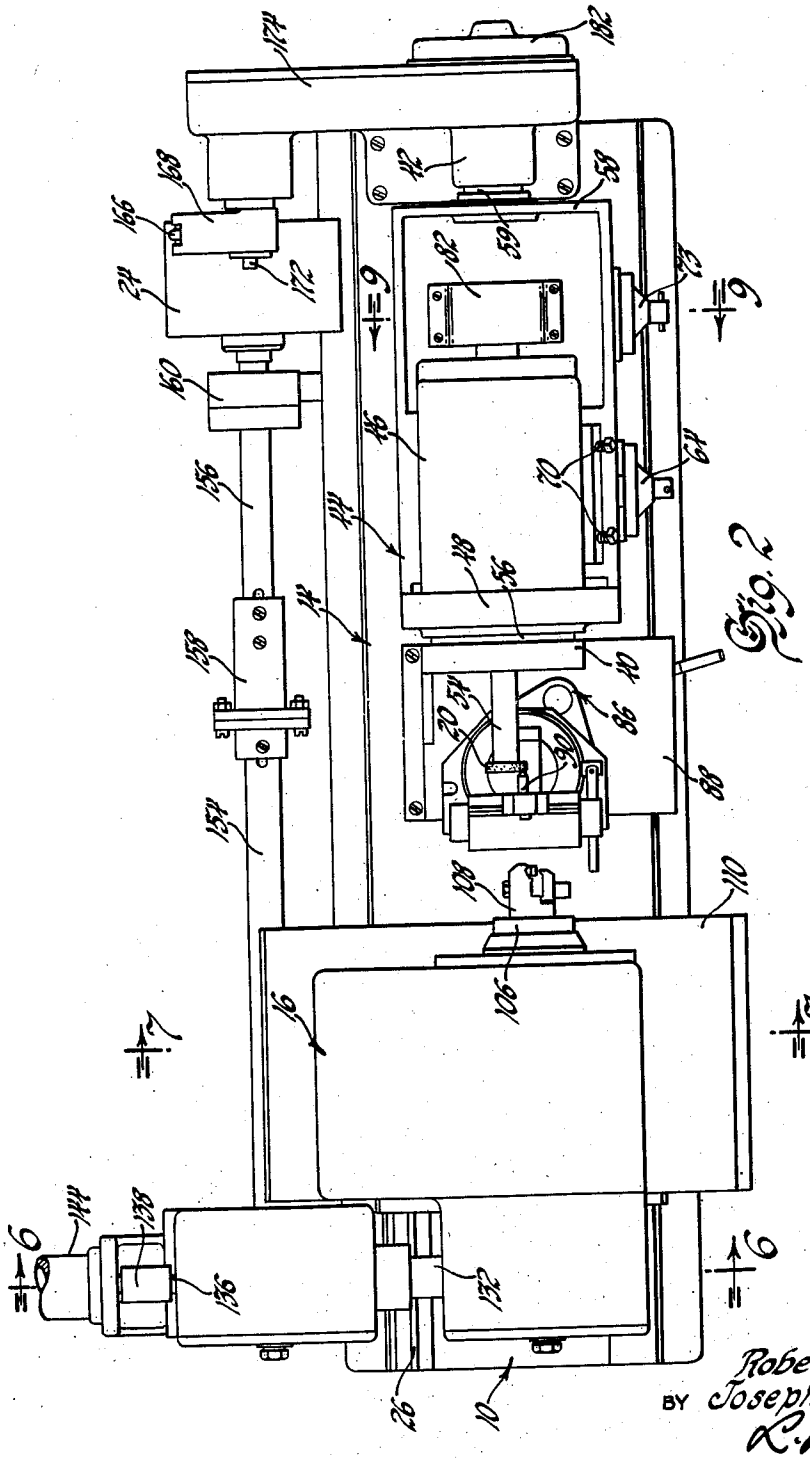


Fig. 2

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GRINDING MACHINE AND METHOD

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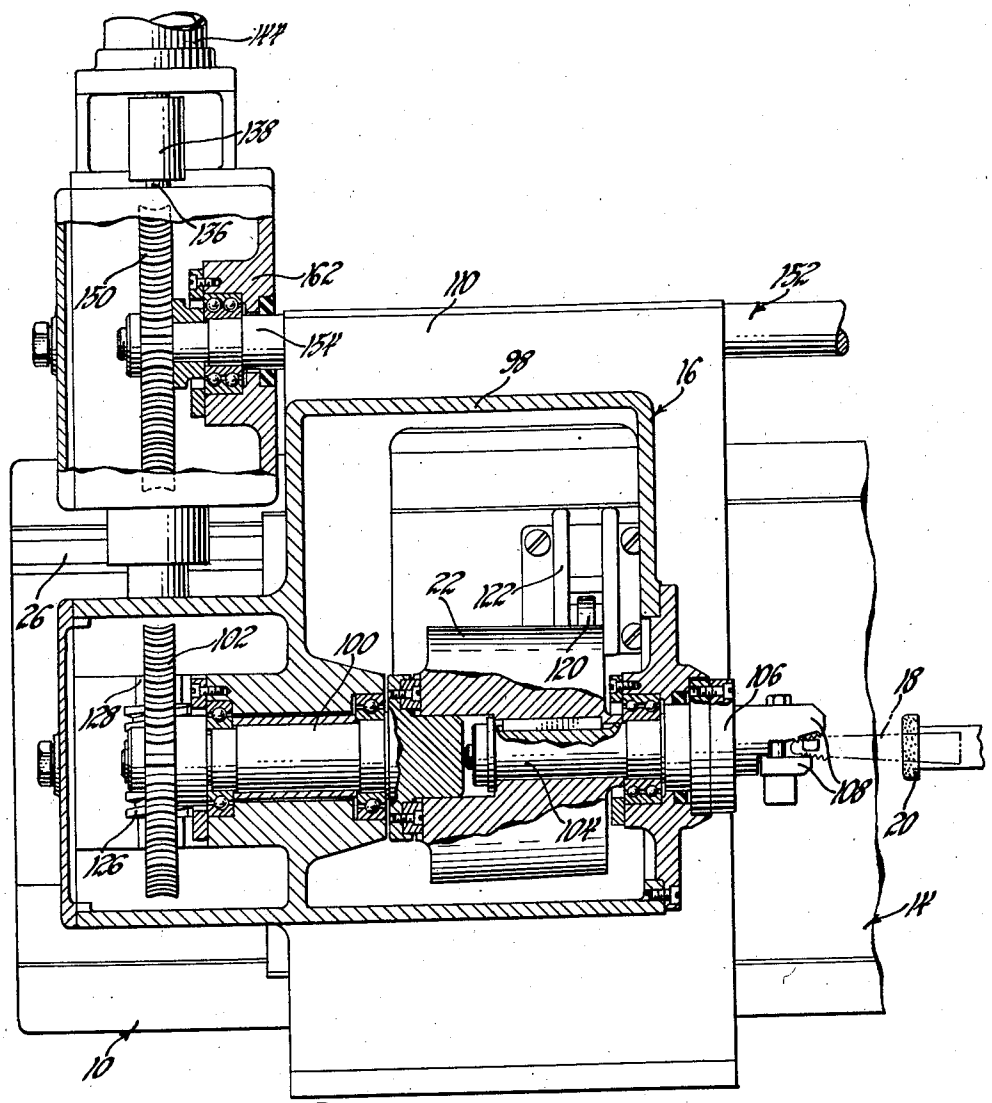


Fig. 3

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GRINDING MACHINE AND METHOD

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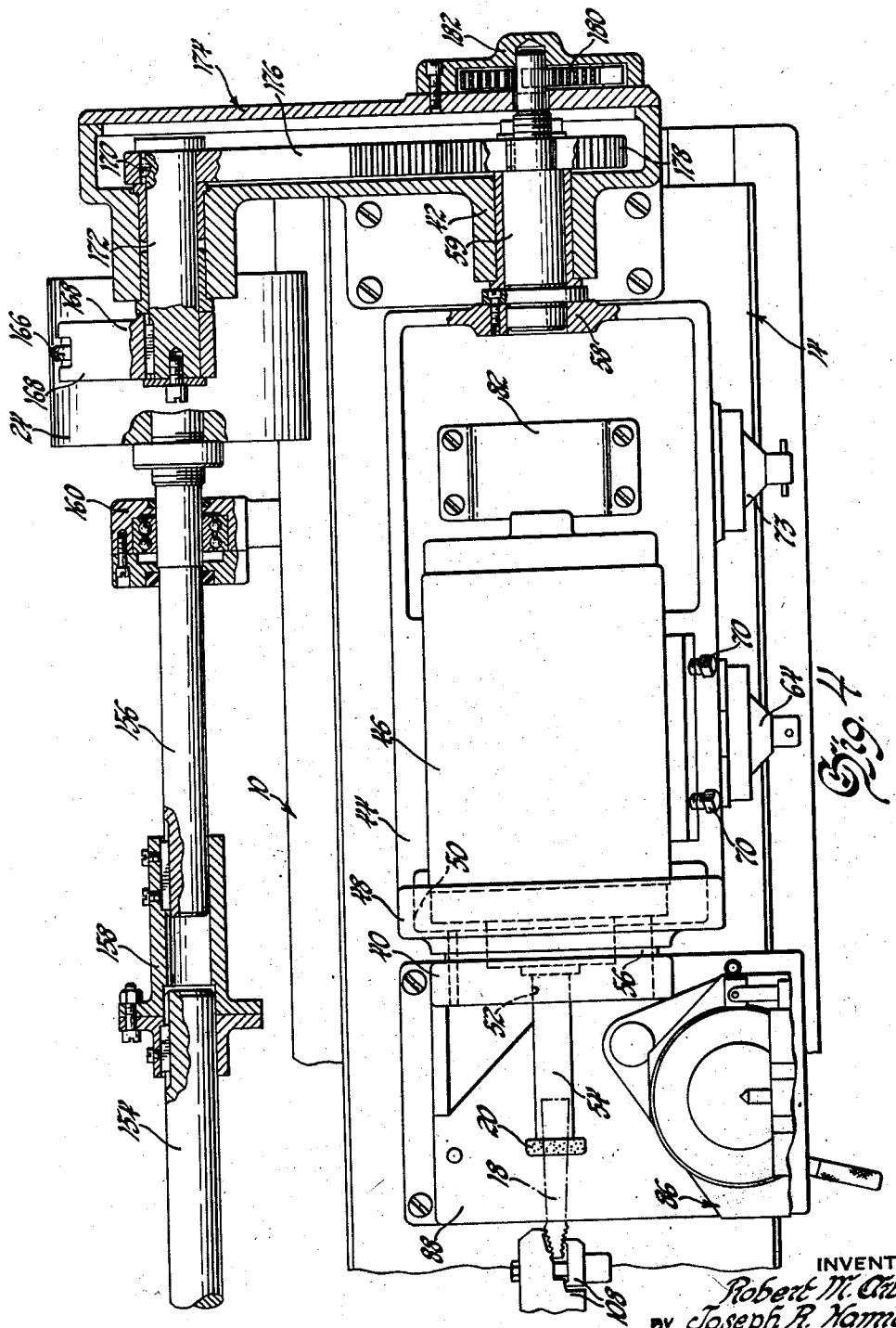


Fig. 11

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GRINDING MACHINE AND METHOD

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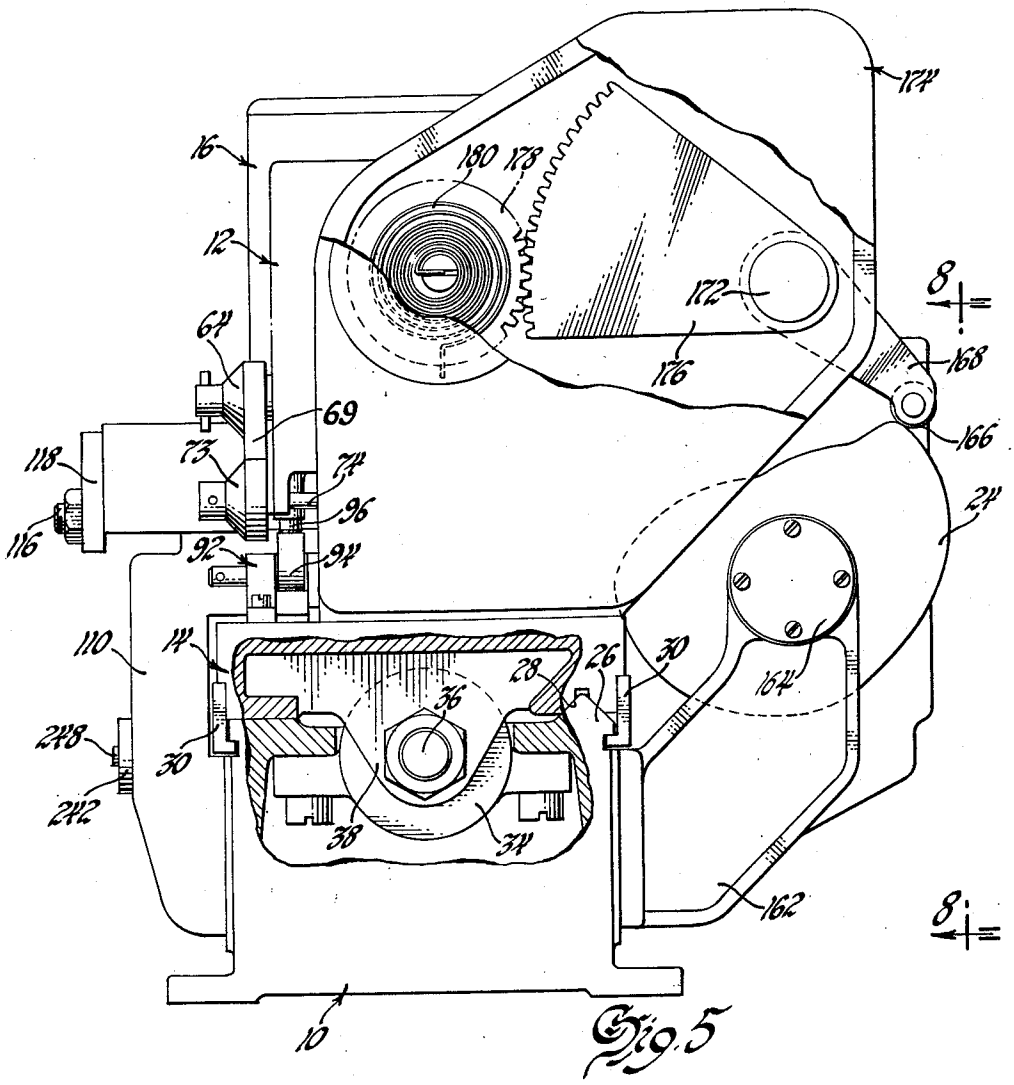


Fig. 5

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GRINDING MACHINE AND METHOD

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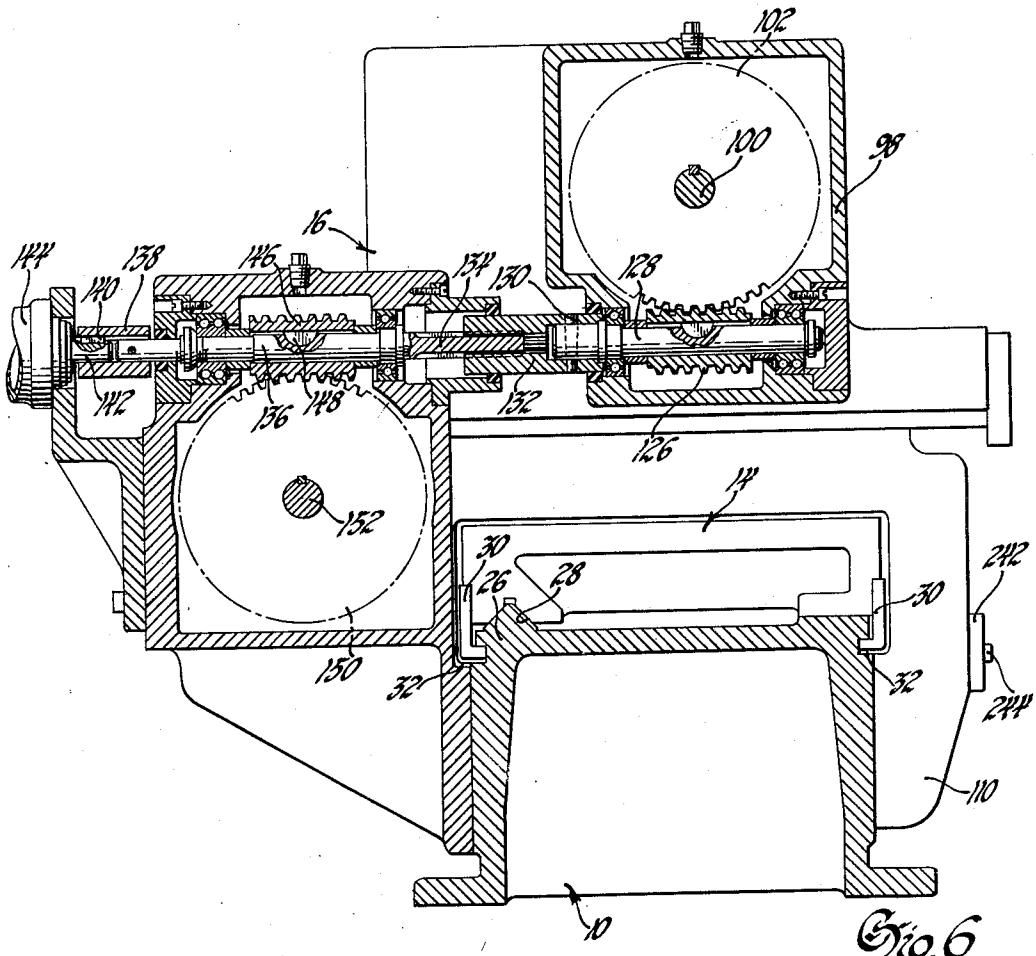


Fig. 6

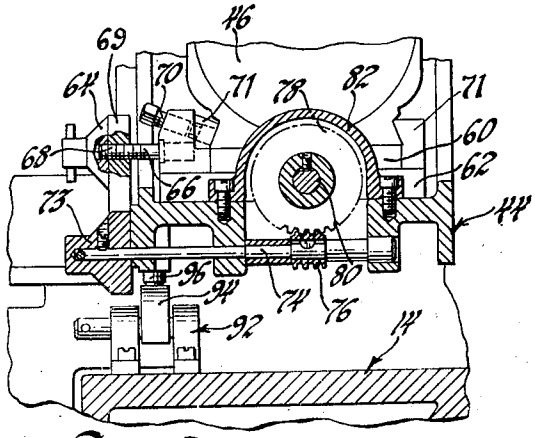


Fig. 9

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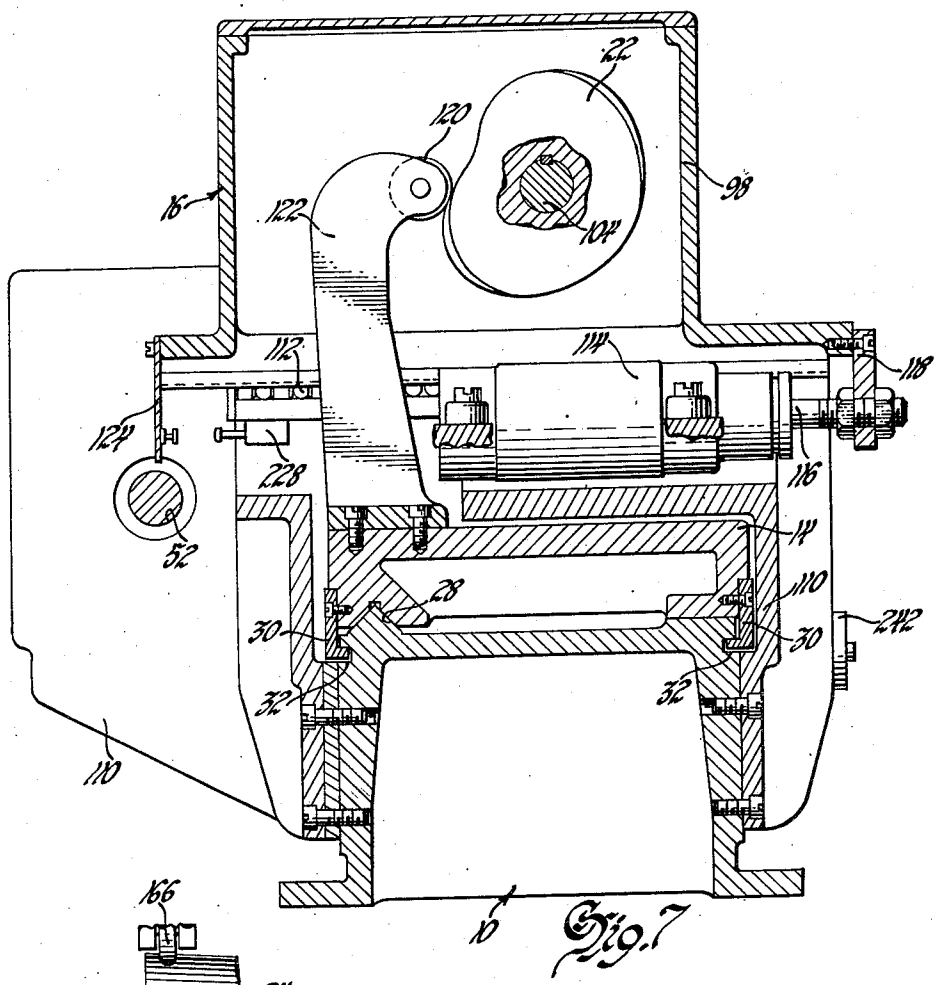


Fig. 7

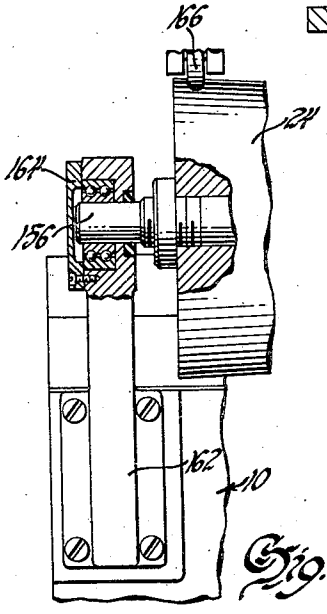


Fig. 8

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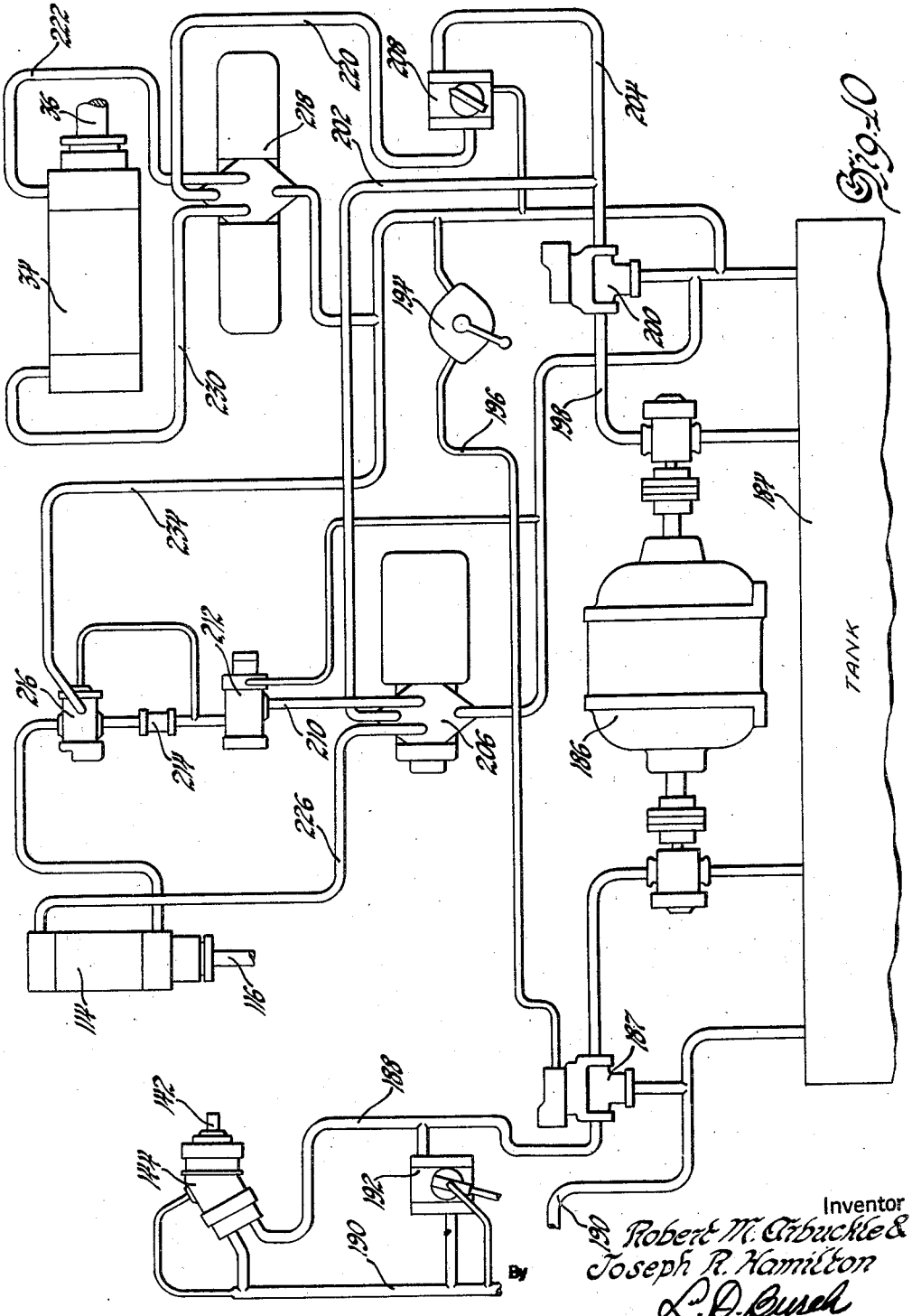


Fig. 10

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GRINDING MACHINE AND METHOD

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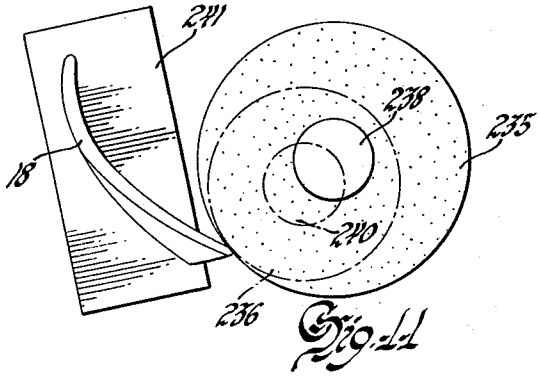


Fig. 11

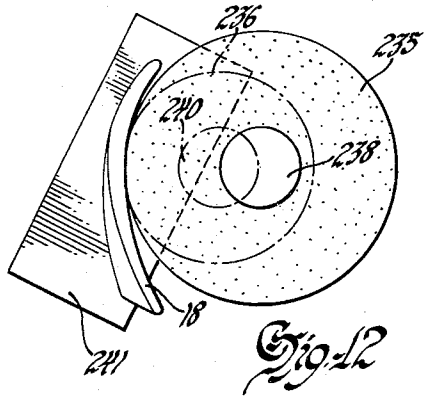


Fig. 12

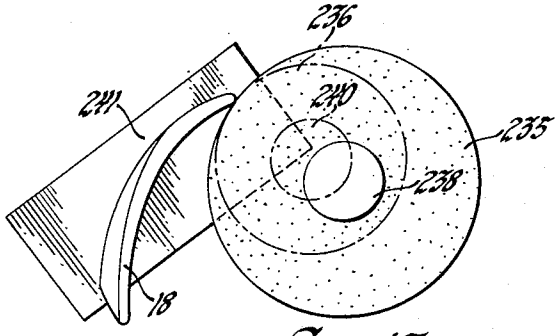


Fig. 13

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United States Patent Office 2,823,492 Patented Feb. 18, 1958

2,823,492

GRINDING MACHINE AND METHOD

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Application July 16, 1954, Serial No. 443,854

7 Claims. (Cl. 51—32)

This invention relates to contour or profile grinding machines and more particularly to machines for grinding forged or rough cast turbine bucket blades to within prescribed tolerances.

In high speed turbines it is necessary that each blade of the turbine wheel be precisely the same or closely identical to every other blade of such wheel. The high speeds at which turbine wheels are rotated accentuates every blade defect and magnifies the resultant unbalance force. In order to prevent the destruction of the turbine wheel and irreparable damage to the turbine and surrounding equipment it has heretofore been necessary that each turbine blade be individually machined to within very close tolerance dimensions to assure their identity within prescribed limits. The machining of each blade individually is costly in time and labor.

It is now proposed to provide a means of grinding a rough cast or forged turbine bucket blade to within the prescribed tolerances. Heretofore such grinding of a turbine blade has been considered impractical because of the wearing away of the grinding wheel and a consequent difficulty in maintaining the prescribed tolerances. The grinding machine proposed is provided with means for obviating this objection by compensating for grinding wheel wear. It is proposed to rotate each turbine blade, in rough form, about an axis parallel to that of the grinding wheel and to move the grinding wheel along the length of the blade as the blade is moved transversely with respect thereto and in conformance with the dictates of a master cam. Inasmuch as the workpiece or blade is moved relative to the grinding wheel and engages the grinding wheel at progressive positions along its peripheral edge it is proposed that a worn grinding wheel may be adapted for such movement as will enable engagement with the workpiece at such progressive positions. Such movement of a worn grinding wheel may be accomplished by mounting the grinding wheel drive motor upon a cradle having a fixed axis of rotation and by eccentrically positioning the axis of the worn grinding wheel from the cradle axis so that rotation of the cradle will cause the worn grinding wheel to describe an arcuate path which will dispose the worn wheel at the progressive positions along the arcuate path which the workpiece is adapted to travel.

It is therefore an object of the proposed invention to provide a machine and method for grinding turbine bucket blades and to provide means for compensating for grinding wheel wear. It is an object of this invention to provide a master cam adapted to control the contour grinding of a rough cast or forged turbine blade and to provide a corrector cam to compensate for grinding wheel wear. It is further an object of this invention to provide a fully automatic profile grinding machine for accurately and rapidly grinding a turbine blade to prescribe tolerances and readily adaptable for repeated operation in grinding numerous blades without renewing the grinding wheel used therewith. The proposed machine is adapted to perform the required grinding operation in a minimum

of time with small cost in labor and materials. The use of forged or cast blades in the proposed machine greatly minimizes the machining time heretofore required. The use of a grinding wheel and its adaptability for continued use despite wear is of great savings in tooling heretofore necessary. The overall cost of producing turbine blades is therefore greatly reduced without a sacrifice of quality and with considerable savings in time, labor, and materials.

Although the principles of this invention are here related to a grinding machine they may obviously similarly be adapted for use in a milling operation wherein a milling cutter wheel rather than a grinding wheel is employed.

Figure 1 is a side view of the proposed profile grinding machine having parts broken away and shown in cross section.

Figure 2 is a top view of the proposed grinding machine taken in the plane of line 2—2 of Figure 1 and looking in the direction of the arrows thereon.

Figure 3 is an enlarged top view of one end of the proposed grinding machine including the work holder and having parts broken away and shown in cross section.

Figure 4 is an enlarged top view of the other end of the proposed machine including the grinding means and having certain parts broken away and shown in cross section.

Figure 5 is an enlarged end view of the proposed grinding machine showing the means for compensating for grinding wheel wear. Figure 5 is taken in the plan of line 5—5 of Figure 1 looking in the direction of the arrows thereon.

Figure 6 is an enlarged cross-sectional view of the other end of the grinding machine taken in the plane of line 6—6 of Figure 2 and viewed in the direction of the arrows thereon.

Figure 7 is an enlarged cross-sectional view taken through the work holder in the plane of line 7—7 of Figure 2 and viewed in the direction of the arrows thereon.

Figure 8 is a view of a part of the grinding machine showing the end mounting of the corrector cam as viewed in the plane of line 8—8 of Figure 5 in the direction of the arrows thereon.

Figure 9 is an enlarged cross-sectional view of a part of the proposed grinding machine taken in the plane of line 9—9 of Figure 2 and viewed in the direction of the arrows thereon.

Figure 10 is a diagrammatic illustration of the fluid lines employed with the proposed grinding machine.

Figures 11, 12 and 13 are diagrammatic illustrations of the relation between the workpiece and grinding wheel during progressive stages of the grinding operation.

The proposed turbine bucket or blade contour grinding machine includes a base member 10 having a work device 12 mounted upon a table 14 slidable upon one end of the base member and work holder 16 mounted upon the other end of the base member and adapted for transverse movement with respect to the table. A workpiece 18 is supported within the work holder 16 and is adapted for rotation and translation relative to the longitudinal movement of a rotating grinding wheel 20 of the work device 12. A master cam 22 mounted in the work holder 16 controls the gyration of the workpiece 18 about the grinding wheel 20 and a correction cam 24 associated with the work device 12 controls the gyration of the grinding wheel relative to the workpiece as necessary to compensate for grinding wheel wear.

Referring to Figure 5, the table 14 is adapted for longitudinal guided movement along the top of the base member 10 by means of a guide rail 26 formed on the base member and received within a groove 28 formed in the underside of the table. Depending side rails 30 of the table 14 overlay the sides of the base 10 and are formed

inwardly to engage grooves 32 provided in the sides of the base member. Movement of the table 14 is effective by a hydraulic cylinder 34 secured to the base member 10 and connected by the piston rod 36 to a depending flange 38 of the table.

Trunnion supports 40 and 42 are secured to the table 14 and are spaced apart to support a cradle 44 therebetween. A grinding wheel drive motor 46 is mounted upon the cradle 44. The forward upright 48 of the cradle 44 and the forward support 40 have enlarged openings 50 and 52 formed therein through which the shaft or drive spindle 54 of the grinding wheel motor 46 is extended; the forward end of the cradle being pivotal upon a pivot bearing ring 56 extended between the support 40 and cradle upright 48. The rearward cradle upright 58 has a pivot shaft 59 secured thereto and journaled within the after support 42.

The grinding wheel drive motor 46 is supported on the cradle 44 on a pair of slide blocks 60 and 62 which enable axial and lateral adjustment of the drive motor relative to the pivotal axis of the cradle member. The drive motor 46 is secured to slide block 60 which is itself adjustable within guideways 71 formed from slide block 62. This slide block 60 is adjustable lengthwise of the cradle by adjustment of the graduated knob 73 connected to shaft 74 having worm 76 on the end thereof and which engages the worm wheel 78 to rotate shaft 80 threaded through a nut member 84 fixed to the underside of the slide 60 (see Figures 1 and 9). The slide block 62 is adjustable transversely of the cradle, within guideways 63 thereof, by means of a graduated knob 64 connected to a shaft 66 which is engaged with the slide and is threaded as at 68 through an upright support 69 secured to the side of the cradle.

Set screws 70 are provided to fix the motor 46, and its longitudinally adjustable slide block 60, in an adjusted position relative to slide block 62. Slide block 62 remains laterally adjustable by threaded shaft 66 (with either shaft 80 having a U-joint therein or nut 84 being pivotally connected to the underside of slide 60).

These adjustments of the grinding wheel motor 46 are provided for the purposes of setting the position of the grinding wheel 20 relative to the workpiece 18 for the work stroke required and for moving the axis of rotation of the grinding wheel from a position coincident with the cradle axis with an unworn grinding wheel to a position off center from the cradle axis commensurate with grinding wheel wear, as will be described.

The grinding wheel 20 is secured to the shaft 54 of the drive motor 46 beyond the trunnion support 40. A grinding wheel dresser 86 is mounted upon the table 14 and is pivotally supported upon a mounting stand 88 for movement into or out of engagement with the face of the grinding wheel 20. The wheel dresser 86 is shown in dressing position in Figures 1 and 2 and as pivoted out of the way in Figure 4. The grinding wheel 20 is moved relative to the dressing member 90 by transverse movement of the grinding wheel motor 46 on slide block 60.

A cradle stop 92 is secured to the table 14 beneath the cradle 44 and comprises a cam 94 adapted to be rotated for engagement or disengagement with a depending lug 96 on the cradle. The engagement of the cam 94 with the lug 96 raises the cradle 44 in a position which prevents rocking the cradle within the supports 40 and 42 as will later be described. When the flat side of the cam 94 is up the cradle 44 is free to rotate.

The work holder 16 includes a housing 98 having a driven shaft 100 journaled therein with a worm wheel 102 secured to one end and the master contour cam 22 secured to the other end. A work spindle 104 is journaled within the work holder housing 98 and is aligned with the driven shaft 100 and secured thereto through a spline connection with cam 22, which is itself connected to a flange of shaft 100. A work chuck 106 with locking jaws 108 is secured to the outer end of the spindle 104 and is adapted to receive the workpiece 18 and to hold the workpiece in outwardly extended relation towards the grinding wheel 20.

The work holder housing 98 is mounted upon a supporting platform 110 secured to the base member 10 and within a ball-track 112 formed transversely across the platform as shown by Figure 1. Referring to Figure 7, a hydraulic power cylinder 114 secured to the platform 110 is connected by a piston rod 116 to a depending portion 118 of the housing 98 and is adapted to urge the housing and more particularly the master cam 22 against a cam follower 120 secured to the table 14. The cam follower 120 includes an upstanding support 122 secured to the table and adapted to dispose the follower adjacent the master cam 22. As the table 14 is moved longitudinally the housing 98 is adapted to move transversely with respect thereto against the bias of the hydraulic cylinder 114. The hydraulic cylinder 114 is further adapted to move the master cam 22 out of engagement with the cam follower 120 by means of the piston rod 116 acting against the depending portion 118 of the housing to the limits of the stop-plate 124 secured to the housing 98 and adapted to engage the platform 110.

Referring to Figures 3 and 6, the worm wheel 102, within the work holder housing 98, is driven by a worm 126 secured to a shaft 128 journaled in the base of the housing. The end of the shaft 128 is pinned as at 130 to a splined female connector 132 which receives the splined end 134 of an intermediate shaft 136 journaled within the platform support 110, thereby allowing relative movement of the work holder housing 98 axially of the intermediate shaft. The intermediate shaft 136 is pinned to a connector 138 keyed as at 140 to the drive shaft 142 of a hydraulic motor or other drive source 144.

A worm 146 keyed as at 148 to the intermediate shaft 136 meshes with a worm wheel 150 mounted upon a second drive shaft 152 extended longitudinally along the outside of the base 10. Referring to Figure 4, the drive shaft 152 includes two parts 154 and 156 joined by a connector 158 and journaled within the platform support 110 and two bearing supports 160 and 162 secured to the base member 10. As shown by Figures 4 and 8, the correction cam 24 is secured to the drive shaft 152 intermediate the two bearing supports 160 and 162. A cover plate 164 is secured to the one support 162 over the end of the drive shaft 152.

A cam follower 166 is adapted to engage the correction cam 24 and is mounted on an extended arm 168 keyed as at 170 to a stub shaft 172 journaled within the rack and pinion housing 174; which housing is integrally a part of the after trunnion support 42 secured to the movable table 14. A rack sector 176 is also secured to the stub shaft 172 and is disposed in meshing engagement with a pinion 178 secured to the cradle pivot shaft 59. A coil spring 180 is secured to the after end of the pivot shaft 59 between the shaft and the cover plate 182 secured to the housing 174 thereover. The spring 180 is adapted to balance the weight of the cradle 44 and thereby assist the rack 176 in moving the cradle.

The cam follower 166 moves with the table 14 longitudinally along the base 10 and thereby is moved along the corrector cam 24. The follower 166 is adapted to normally engage the cam 24 at its smallest radius. The follower 166 is held in engagement with cam surfaces of larger radius by the gravitational weight of the cradle 44 which at such larger radii acts to bias the follower against the corrector cam 24.

The operation of the grinding machine is hydraulically controlled. In Fig. 10 there is shown a fluid tank 184 and pump motor 186 which may be disposed apart from the grinding machine but which are connected thereto by fluid lines as hereinafter described. The main drive motor 144 of the contour grinding machine is connected

by lines 188 and 190 to the fluid tank 184. In the present instance a constant displacement piston type fluid motor is used. A cam operated metering or flow control valve 192 is connected between the flow lines 188 and 190 to regulate the speed of the drive motor 144 by control of the fluid flow. A pilot valve 194 is connected by line 196 to a control valve 187 in line 188 for starting the fluid drive motor 144.

Fluid from the tank 184 is conveyed through line 198 to the control valve 200 which when actuated allows fluid to pass through lines 202 and 204 to control valve 206 and to the flow metering valve 208 respectively. Fluid passing through the control valve 206 is normally adapted to flow through line 210 past the pressure reducing valve 212, check valve 214 and relief valve 216 to one side of the hydraulic cylinder 114 for controlling movement of the work holder housing 98 in one direction. Such direction is normally to bias the master cam 22 against the cam follower 120. The fluid passing through the metering valve 208 reaches control valve 218 through line 220 where it is applied via line 222 to one side of the hydraulic cylinder 34 connected to the base 10 and adapted to move the table 14 in one direction by means of piston rod 36 connected to the depending flange 38 thereon.

The table 14 advances at a rate set by the metering valve 208. The work holder housing 98 is moved transversely thereto by the cam follower 120 engaged against the master cam 22 until the bracket 223 of table 14, as shown by Figure 1, contacts limit switch 224. The actuation of limit switch 224 stops the travel of table 14 and diverts the fluid flow through control valve 206 from line 210 to line 226 where it is introduced to the other side of the hydraulic cylinder 114. Referring to Figure 7, the work holder housing 98 is moved in a direction to dispose the master cam 22 beyond the reach of the cam follower 120. The work holder housing 98 engages limit switch 228 at the end of its travel which switch diverts the fluid flow through control valve 218 from line 222 to line 230 and causes a rapid return of the table 14 to its original position. The table 14 contacts limit switch 232 which is adapted to shut off the grinding wheel drive motor 46.

A control panel 242 is secured to the machine in any convenient location as to the support 110 and includes three separate control buttons 244, 246 and 248 connected to various units of the proposed machine in a conventional and well known manner. The button 244 actuates the control valves 206 and 218 to start the advance of the work holder and table, the button 246 starts the grinder motor 46 and the button 248 is for the immediate return of the work holder 96 and table 14 to their original positions. In an emergency the work holder housing 98 is backed-off and the slide table 14 returned, with a consequent shutting off of the grinding wheel drive motor 46, by the actuation of button 248 diverting the flow of fluid away from hydraulic cylinder 114, through relief line 234, and directly back to the fluid tank 184. The fluid is at the same time diverted through line 226 to the other side of the hydraulic cylinder 114 causing the work holder housing 98 to back off, actuating limit switch 228, diverting fluid flow in cylinder 34, and returning the table 14 to its original position.

A general diagrammatic representation of the relation of the workpiece 18 and grinding wheel 20 is given in Figures 11, 12 and 13. These figures show a new grinding wheel 235, a worn wheel 236, and their respective drive spindles 238 and 240 respectively. The workpiece 18, or turbine blade as here shown, is illustrated against a rectangular background 241, representative of the blade holding means, to more clearly designate the change in position through the three stages given. The relation of the blade to the representative holding means is unchanging.

Taking into consideration first a new grinding wheel 235 which is not worn, it will be seen that the rocking of the cradle 44 caused by the engagement of the cam follower 166 with the correction cam 24, through the rack and pinion 176 and 178, will not affect the grinding wheel since its axis of rotation is coaxial with the pivotal axis of the cradle. The workpiece 18 is rotated and moved relative to the grinding wheel 20 in conformance with the dictates of the master cam 22 as the table 14 moves the grinding wheel 235 along the length of the workpiece. The workpiece 18 rotates about its own axis and is moved transversely to the grinding wheel 235 as prescribed by the master cam 22 and engages the grinding wheel 235 so far as is necessary to perform the required tolerance grinding. The master cam 22 controls the grinding of both sides of the workpiece 18 as the grinding wheel 235 moves inwardly therealong.

After the grinding wheel 235 becomes worn to the size of wheel 236 it is apparent that the wheel being smaller in diameter cannot grind to the required tolerance. It is therefore necessary that the wheel 236 be disposed in such a manner that its grinding surface will follow the peripheral path of the original wheel 235. This is accomplished by moving the slide block 60 upon which the grinding wheel motor 46 is mounted an amount equal to the wear of the original wheel 235. The threaded shaft 66 is accordingly rotated by knob 64 moving the slide block to relocate the drive spindle 54 off center from the axis of cradle 44. The rocking of the cradle 44 caused by the corrector cam 24 and follower 166 through the rack and pinion 176 and 178 will now cause the grinding wheel 236 to move along an arcuate path as prescribed by the corrector cam 24 for movement of the cradle 44. The grinding wheel 236, though worn, is thus adapted to describe the same path as the unworn wheel 235 insofar as it is disposed at the position of the unworn wheel's engagement with the workpiece 18. The corrector cam 24 is adapted to cause the grinding wheel 236 to describe a path of movement such as will dispose the wheel in grinding engagement with the workpiece 18 at all times as required to perform the desired tolerance grinding.

In operating the proposed profile or contour grinding machine it is first necessary to provide a properly dressed grinding wheel. The wheel dresser 86 is moved into position, the cradle locked by stop 92, the grinding wheel 20 rotated and the face of the wheel adjusted relative to the dressing member 90 by movement of the grinding motor 46 on the slide block 60. The dressing member 90 is then moved across the face of the wheel in a conventional manner. When the dressing operation is completed the grinding motor 46 is stopped, the stop 92 disengaged from the cradle, and the wheel dresser 86 pivoted to the side of the machine and out of engagement with the grinding wheel.

The maximum work stroke to be taken, that is lengthwise of the workpiece 18 and toward its shank, is next set by longitudinal adjustment of the grinding wheel 20 through movement of slide block 60 upon which the grinder motor 46 is mounted.

Consideration is next made of the size of the grinding wheel 20 to determine whether or not the wheel is such as requires that the drive spindle 54 be relocated relative to the axis of rotation of cradle 44. Although the wear after each grinding operation may not be appreciable, the operator should check the size of the wheel after each operation to ascertain whether or not wear correction should be made. This step may be accomplished in the course of dressing the grinding wheel.

Following the adjustment of the disposition of the drive motor 46 as required to properly align the grinding wheel 20 with respect to the cradle axis, the workpiece 18 is next inserted in the chuck 106 and locked within the jaws 108 with the portion to be ground ex-

tended outwardly towards the grinding wheel 20. The workpiece 18 is a roughly cast or forged member which is required to be brought within prescribed tolerances. The general contour of a turbine blade is therefore present and only minimal grinding is required.

Having fluid supplied to all fluid lines preparatory to operation, that is those which are adapted to carry fluid at the first stages, the pilot valve 194 is opened to start the fluid motor 114. The workpiece 18 is rotated at a speed prescribed by the setting of the metering valve 192. Neither fluid cylinder 34 or 114 is activated, the fluid passing directly through the control valves 206 and 218 and returning to the tank 184. The grinder motor 46 is activated and the grinding wheel 20 rotated at its prescribed speed. The wheel 20 is at this moment spaced apart from the workpiece 18.

The machine operation is initiated by start button 244 which is connected to control valve 206 diverting fluid flow to the hydraulic cylinder 114 and moving the master cam 22 into engagement with cam follower 120. After a short time delay to effect such engagement the fluid flow through control valve 218 is diverted to one end of the hydraulic cylinder 34 moving the slide table 14 and consequently the grinding wheel 20 into grinding engagement with the workpiece 18. As the workpiece 18 is rotated and moved transversely in conformance with the dictates of the master cam 22 the grinding wheel 20 progresses lengthwise therealong. With compensation being made for wear of the grinding wheel 20 the cradle 44 will be rocked by the rack and pinion 176 and 178 to enable the worn grinding wheel 20, if such be in use, to follow the arcuate path which would normally be the peripheral edge of a new grinding wheel.

When the table 14 has moved the grinding wheel 20 along the preset length of the workpiece 18, the table contacts limit switch 224. The table 14 is stopped and dwells in such end position during which time the fluid flow to hydraulic cylinder 114 is diverted from one end to the other causing the work holder housing 98 to back off the master cam 22 from the cam follower 120. When the master cam 22 has been moved out of engagement with the follower 120 the housing 98 engages limit switch 228 which causes fluid to be diverted from one end of the hydraulic cylinder 34 to the other for rapidly returning the table 14 to its original position. The table 14 in returning engages limit switch 232 cutting off the grinder motor 46. The pilot valve 194 is then shut off and the finished workpiece 18 removed from the chuck 106.

The setting of the grinding wheel 20 relative to the axis of cradle 44 should be checked prior to inserting another rough workpiece 18 in the work chuck 106 and repeating the operation.

We claim:

1. The method of compensating for work tool wear in a profiling machine having the work surface of a work member adapted to generate an arcuate path about the rotational axis of a preferred work tool, which method includes disposing the working edge of a worn work tool tangentially of said arcuate path, and oscillating said worn tool in an arcuate path concentric with said first-mentioned arcuate path and in timed relation with the movement of said work surface within said arcuate path for maintaining said working edge in continuous working engagement with said work member.

2. The method of compensating for grinding wheel wear in a profile grinding machine having the work surface of a work member adapted to generate an arcuate path coincident with the periphery of a grinding wheel of preferred diameter, which method includes displacing the axis of a worn grinding wheel in parallel spaced relation to the axis of said grinding wheel of preferred diameter a distance disposing the periphery of said worn wheel tangentially of the arcuate path of travel of the work surface of said work member, and oscillating said worn wheel about the axis of said grinding wheel of preferred diameter in timed relation with the movement of said work surface within said arcuate path for maintaining continuous working engagement between said worn wheel and said work member.

3. The method of compensating for grinding wheel wear in a profile grinding machine having a workpiece rotated about a given axis and the irregular external work surface thereof moved in an arcuate path concentric with said given axis, which method includes, mounting a worn grinding wheel for rotation about a chosen axis, disposing said chosen axis in parallel spaced relation to said given axis and the working periphery of said worn wheel within the arcuate path traveled by said workpiece, oscillating said worn grinding wheel about said fixed axis, and controlling the oscillation of said worn wheel to maintain the working periphery thereof in engagement with the work surface of said workpiece moving in said arcuate path.

4. A profile grinding machine including means for receiving a work member and translating the surface thereof to be worked along an arcuate path, means for receiving a work tool and disposing the working surface thereof on said arcuate path, said last-mentioned means being adjustable relative to said arcuate path and having means operatively connected thereto for oscillating the working surface of said work tool along said arcuate path for continuous working engagement with said work member.

5. In a machine adapted to receive a workpiece and to have the surface thereof to be worked translated along an arcuate path for engagement with a work tool, means for compensating for work tool wear which includes, tool holder means adjustable relative to said arcuate path and adapted to receive a work tool and dispose the working surface thereof on said arcuate path, and means operatively connected to said tool holder means for oscillating the working surface of said tool along an arcuate path coincident with said first-mentioned arcuate path and in timed relation to the movement of said workpiece surface for continuous working engagement with said workpiece.

6. A profiling machine comprising a work holder for receiving a work member for rotation, a cradle including a tool holder for receiving a work tool for rotation, means connected to said tool holder for moving said tool holder towards said work holder, means connected to said work holder for moving said work holder transversely of the direction of travel of said tool holder, means operatively connected to said work holder for coordinating the movements of said work member relative to said tool holder and moving the work surface thereof in an arcuate path relative to the pivotal axis of said cradle, means displacing the axis of rotation of the work tool received by said work holder in parallel spaced relation to the pivotal axis of said cradle for disposing the peripheral edge thereof on the arcuate path traveled by the work surface of said work member, and means operatively connected to said cradle for rocking said cradle, the rocking of said cradle translating the peripheral work engaging surface of said work tool in an arcuate path coincident with the arcuate path traveled by the work surface of said work member.

7. A profiling machine comprising a work holder for receiving and rotating a workpiece having an irregular external work surface and for translating said workpiece normal to the axis of rotation thereof, a rotatable work tool and means for oscillating said rotatable tool in an arcuate path about a reference axis of gyration, means for feeding said tool towards and away from said workpiece, and cam and drive means interconnected with said work holder and tool oscillating means for rotating and translating said workpiece in timed relation to the oscil-

lating and feeding means controlling said work tool for maintaining said irregular work surface in constant engagement with said work tool.

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