

Dec. 7, 1937.

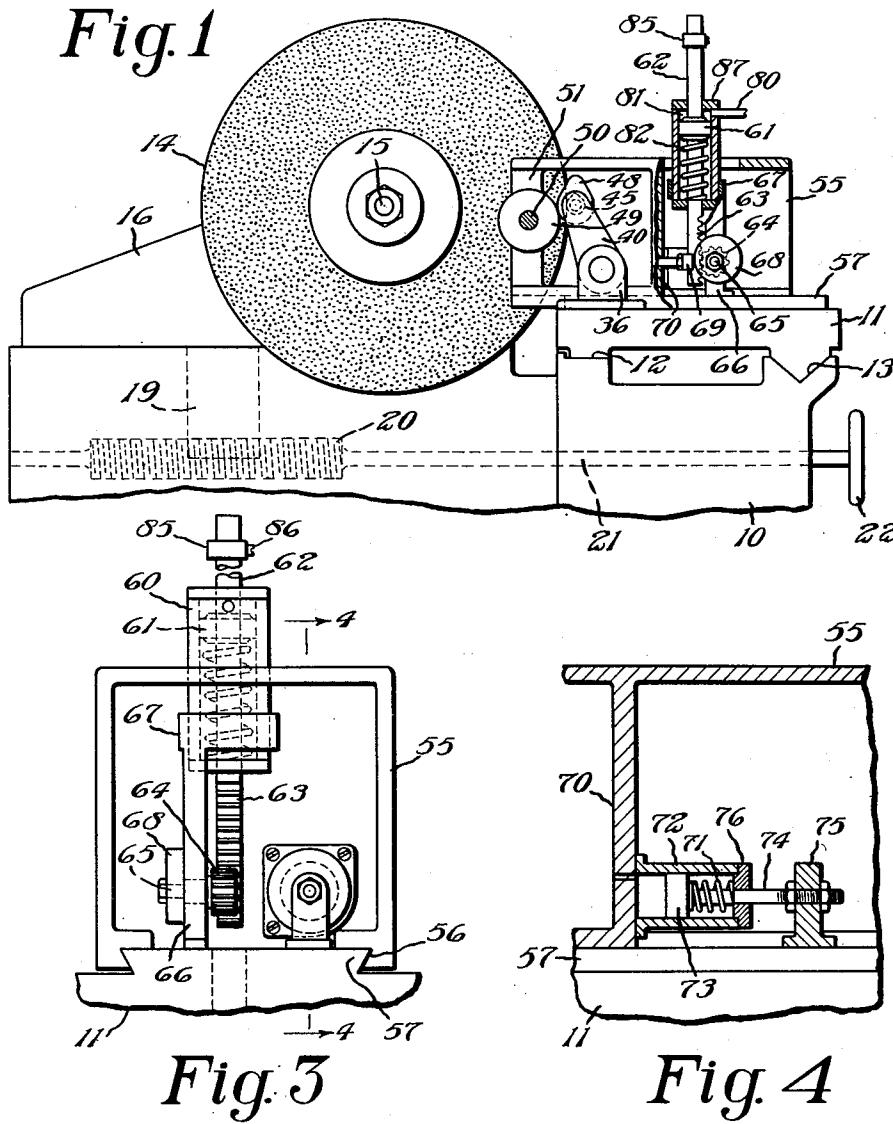
C. J. GREEN

2,101,796

CAM GRINDING APPARATUS

Filed Nov. 27, 1936

3 Sheets-Sheet 1



Inventor
CLARENCE J. GREEN

By *Harold W. Eaton*
Attorney

Dec. 7, 1937.

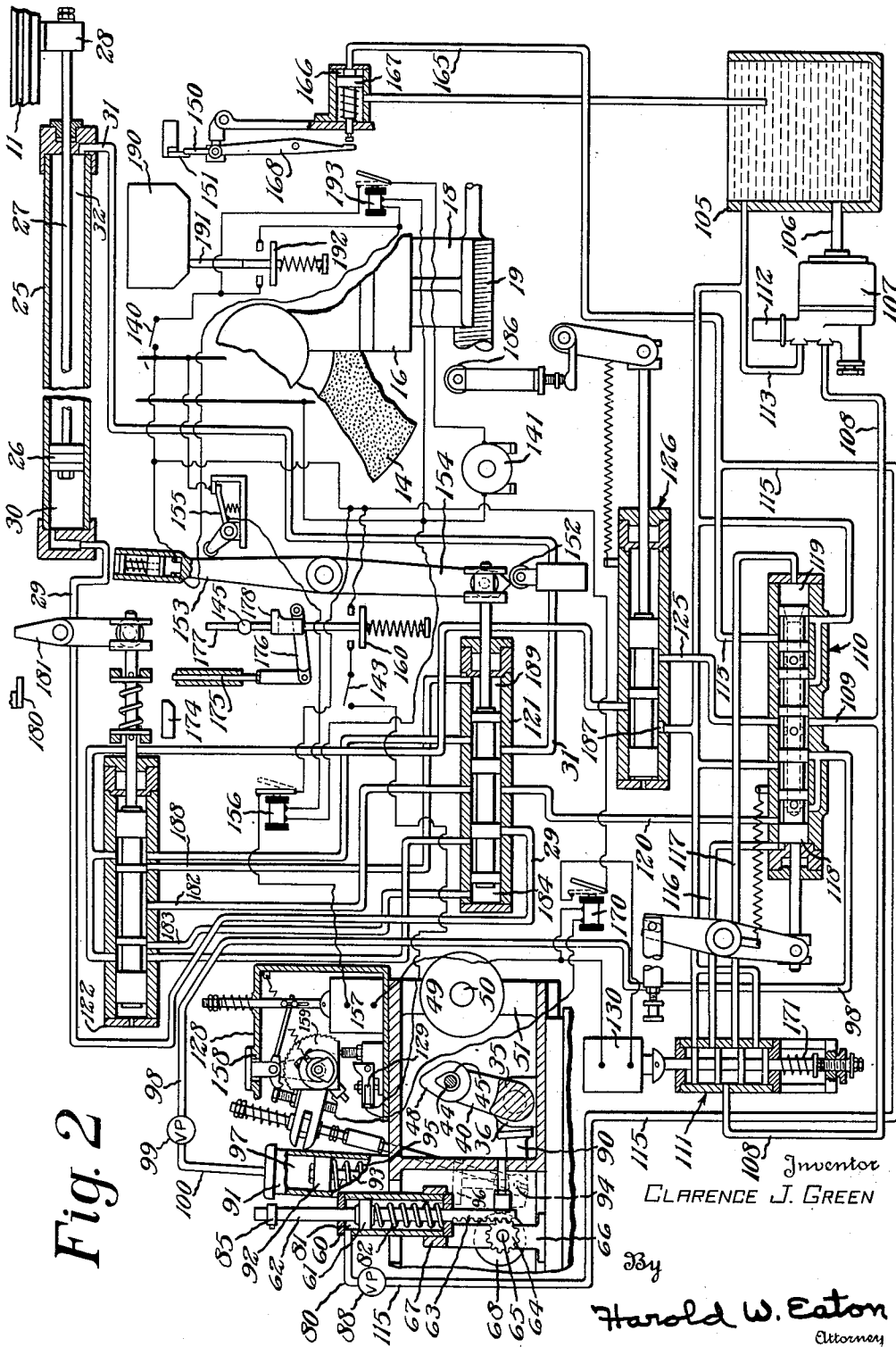
C. J. GREEN

2,101,796

CAM GRINDING APPARATUS

Filed Nov. 27, 1936

3 Sheets-Sheet 2



Dec. 7, 1937.

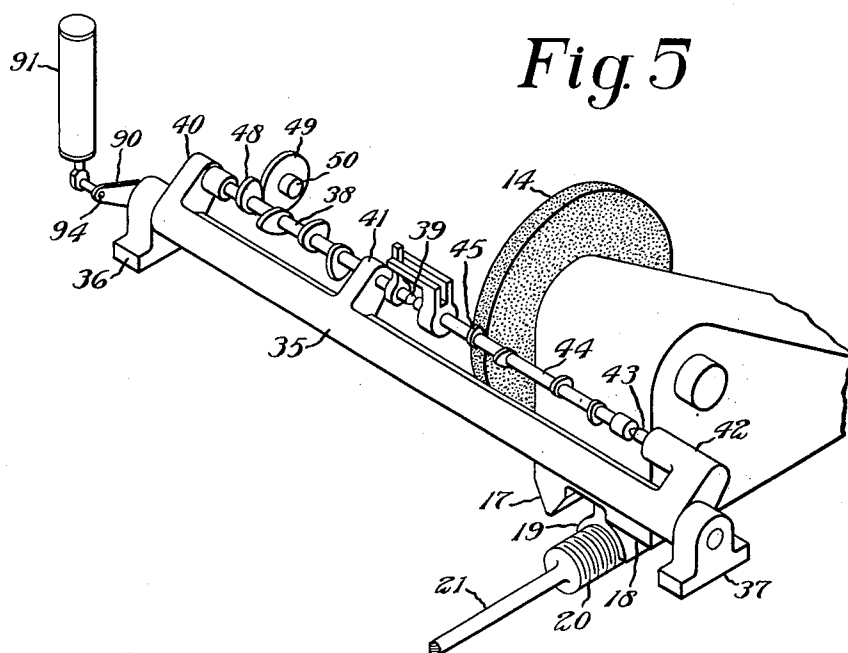
C. J. GREEN

2,101,796

CAM GRINDING APPARATUS

Filed Nov. 27, 1936

3 Sheets-Sheet 3



Inventor
CLARENCE J. GREEN

334 Harold W. Eaton
Attorney

UNITED STATES PATENT OFFICE

2,101,796

CAM GRINDING APPARATUS

Clarence J. Green, Worcester, Mass., assignor to
Norton Company, Worcester, Mass., a corpo-
ration of Massachusetts

Application November 27, 1936, Serial No. 112,949

10 Claims. (Cl. 51—101)

The invention relates to grinding machines, and more particularly to a camshaft grinding machine.

One object of the invention is to provide a simple and thoroughly practical machine for grinding a plurality of cam blanks on an integral camshaft. A further object of the invention is to provide an improved mechanism for producing a relative feeding movement between the cam blank and the grinding wheel to facilitate grinding the cam blanks to a predetermined size. Another object of the invention is to provide an automatic cam grinding machine with an improved feed control mechanism in which the master cam and master cam roller are actuated to control both the contour and sizing of the cam blanks. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts, as will be exemplified in the structure to be hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which is shown one of the possible embodiments of the mechanical features of this invention,

Fig. 1 is a fragmentary end elevation of a grinding machine, having parts broken away and shown in section to show the improved feeding mechanism;

Fig. 2 is a diagrammatic view, showing the piping diagram and the electrical control circuit;

Fig. 3 is a fragmentary front elevation, on an enlarged scale, showing the improved feeding mechanism;

Fig. 4 is a fragmentary sectional view, taken approximately on the line 4—4 of Fig. 3; and

Fig. 5 is a fragmentary perspective view, showing the arrangement of the master cams, master cam follower, camshaft and grinding wheel support.

A cam grinding machine has been illustrated in the drawings having a base 10 which supports a longitudinally movable work table 11 on a flat way 12 and a V-way 13. The base 10 also supports a rotatable grinding wheel 14 which is mounted on a rotatable wheel spindle 15 journaled in bearings (not shown) in a transversely movable wheel slide 16.

The wheel slide 16 may be adjusted transversely relative to the base 10 by a feeding mechanism which may be actuated either manually or automatically, as desired. In the preferred construction, the wheel slide 16 is provided with a

depending nut 18 which meshes with a rotatable feed screw 20 which is rotatably supported in bearings (not shown) in the base 10. The feed screw 20 is provided with an integral shaft 21 which extends from the front of the machine base. A manually operable hand wheel 22 is mounted on the end of the feed screw shaft 21 and is arranged so that it may be rotated to cause a transverse adjustment of the wheel 14 either toward or from the work supporting table 11.

The work supporting table 11 is moved longitudinally relative to the base 10 by means of a hydraulically operated mechanism comprising a cylinder 25 which is fixed to the base 10. A piston 26 is slidably mounted within the cylinder 25 and is connected by means of a piston rod 27 with a bracket 28 depending from the table 11. Fluid under pressure may be admitted either through a pipe 29 into a cylinder chamber 30 (Fig. 2) or it may be admitted through a pipe 31 into a cylinder chamber 32 to cause the piston and work supporting table 11 to move toward the left (Fig. 2). The admission of fluid under pressure to the cylinder chambers 30 and 32 is controlled by a valve mechanism to be hereinafter described.

The longitudinally movable work table 11 supports a pivotally mounted rock bar 35 which is supported in bearings 36 and 37 which are fixedly mounted on the upper surface of the table 11 (Figs. 1 and 5), and is arranged so that it may be rocked about an axis which is substantially parallel to the axis of rotation of the grinding wheel 14. The rock bar 35 is provided with a rotatable shaft or headstock spindle which, as illustrated in the drawings, may be designated a master camshaft 38 having a camshaft supporting center 39. The master camshaft 38 is supported in bearings 40 and 41. The rock bar 35 also supports a footstock 42 which in turn is provided with a footstock center 43. The headstock center 39 and the footstock center 43 are arranged rotatably to support a camshaft 44 having a plurality of cams 45 to be ground.

In order that the cams 45 on the camshaft 44 may be ground to a predetermined size and contour, it is desirable to provide a plurality of master cams 48 for controlling the rocking movement of the rock bar 35 so as to rock the camshaft 44 being ground toward and from the periphery of the grinding wheel 14 so as to generate a predetermined shape on the cam blanks 45. A plurality of master cams 48 are mounted on the headstock spindle or master camshaft 38

in axial alignment with the axis of the camshaft 44 being ground. A master cam roller or follower 49 is slidably mounted on a rotatable shaft 50 which is rotatably supported in a pair of spaced brackets 51 (Fig. 1). The master cam roller 49 is preferably indexed automatically as the table 11 is moved longitudinally to position the master cam roller 49 opposite the master cam 48 which corresponds to the cam 45 being ground on the camshaft 44. The details of the master cam roller indexing mechanism have not been illustrated since this feature is not considered part of the present invention. For a detailed disclosure of the automatic shifting of the master cam roller, reference may be had to the prior United States Patent No. 1,783,755 to Trefethen and Belden dated December 2, 1930 and also to the United States Patent No. 2,022,178 to Belden and Silven dated November 26, 1935.

In order to grind the cam blank not only to a predetermined contour but also to a predetermined size, it is desirable to provide a feeding mechanism for causing a relative approaching and receding movement between the cam 45 being ground and the grinding wheel 14. In the preferred form of this invention, I provide a feeding mechanism which causes the master cam roller 49 to approach or recede from the axis of the grinding wheel so as to change the position of the stroke of oscillation of the rock bar 35 and to produce either a relative approaching or receding movement between the cam 45 being ground and the grinding wheel 14. In the construction as illustrated in the drawings, the spaced brackets 51 which form a rotatable support for the shaft 50 and master cam roller or follower 49 are formed as an integral part of a transversely movable slide 55 which is provided with a dovetailed slideway 56 mating with a dovetailed projection 57 which is formed integral with the table 11.

In the preferred form, a hydraulically actuated feeding mechanism is provided comprising a fluid pressure cylinder 60 which supports a slidably mounted piston 61 on a piston rod 62. The piston rod 62 extends through both ends of the cylinder 60 and is provided with a rack bar 63 at its lower end which meshes with a gear 64 rotatably supported on a shaft 65 which is journaled in a bracket 66 which is fixed to the upper surface of the dovetailed way 57. The cylinder 60 is supported by an upwardly extending bracket 67 which is formed integral with the bracket 66. A cam or eccentric 68 is mounted on the outer end of the shaft 65 and is arranged to engage a follower 69 which is fixedly mounted to a web 70 formed integral with the slide 55. It will be readily apparent from the foregoing disclosure that when the cam or eccentric 68 is rotated by the rack 63 and gear 64, a transverse movement will be transmitted to the slide 55 to feed the master cam roller 49 so as to cause the camshaft 44 and cam 45 being ground to approach or recede from the grinding wheel 14, so that it may be ground to a predetermined size.

It is desirable that a suitable mechanism be provided to hold the follower 69 in engagement with the periphery of the cam or eccentric 68. A spring pressure device is preferably utilized comprising a spring 71 which is enclosed within a cylinder 72. The cylinder 72 contains a slidably mounted piston 73 which is connected by a piston rod 74 with a bracket 75 which is fixedly mounted on the upper surface of the dovetailed way 57. The compression spring 71 surrounds the piston

rod 77 and is interposed between the piston 73 and a cylinder head 76 which encloses the lower end of the cylinder 72. The compression spring 71 is arranged to move the slide 55 in a direction toward the right (Figs. 1 and 4) so as to maintain the follower 69 in operative engagement with the eccentric or cam 68.

When it is desired to cause an infeeding movement of the camshaft 44 toward the grinding wheel 14, fluid under pressure is admitted through pipe 80 into a cylinder chamber 81 to cause a downward movement of the piston 61 which serves to move the rack bar 63 downwardly and rotates the gear 64 in a counterclockwise direction (Fig. 1), thereby rotating the shaft 65 and cam or eccentric 68 in a clockwise direction (Fig. 1) to transmit a transverse movement to the slide 55 through the follower 69 and thereby shifts the axis of the master cam roller shaft 50 toward the axis of the grinding wheel spindle 15 so as to feed the cam blank 45 being ground into the operative face of the grinding wheel 14 to grind the cam blank to a predetermined size.

A spring 82 surrounding the piston rod 62 and interposed between the piston 61 and the lower cylinder head serves to cause an upward movement of the piston 61 when the fluid under pressure in the pipe 80 is cut off. This upward movement of the piston 61 rotates the cam or eccentric 68 in a clockwise direction to cause a transverse movement of the slide 55 toward the right (Fig. 1) to cause the master cam roller shaft 50 to recede from the axis of the wheel spindle 15 so as to cause a separation of the cam 45 and the grinding wheel 14.

It is desirable to provide a suitable means for stopping the infeeding movement when the cam has approached the grinding wheel and has been ground to a predetermined size. An adjustable collar 85 is provided on the piston rod 62 and is arranged to be locked in adjusted position thereon by means of a set screw 86. The stop collar 85 is arranged so as to engage the upper surface of a cylinder head 87 and thereby to limit the downward movement of the rack 63 and the rotary movement of the feed cam or eccentric 68. The rate of infeeding movement of the cam may be regulated by a valve 88 in the pipe 80. Fluid under pressure is admitted through the valve 88 and pipe 80 by a mechanism to be hereinafter described.

In order that the master cams 48 may be maintained in operative engagement with the master cam roller 49 during the grinding operation on a cam blank 45, a yieldable pressure device is provided which serves yieldingly to maintain the master cam 48 in contact with the follower roller 49. As shown in the drawings, the rock bar 35 is provided with an arm 90. A cylinder 91 is pivotally supported on a bracket by means of a circular clamping band (not shown). The cylinder 91 contains a piston 92 which is connected by a piston rod 93 with a stud 94 on the arm 90. A spring 95 surrounds the piston rod 93 and is contained within the cylinder 91 between the piston 92 and a cylinder head 96 which is fixed in the lower end of the cylinder 91. The spring 95 is compressed to a sufficient extent to maintain the master cam 48 in operative contact with the master cam roller 49 during the grinding operation.

A fluid pressure mechanism is provided to rock the rock bar 35 to an inoperative position automatically before the table 11 is traversed, so that the master cam 48 and follower roller 49

and the product cam 45 and grinding wheel 14 will be separated before the traversing of the table 11 is started. This mechanism may comprise a cylinder chamber 97 within the cylinder 91. When fluid under pressure is admitted through a pipe 98, an adjustable throttle valve 99 and a pipe 100, into the cylinder chamber 97, the piston 92 is moved downwardly, compressing the spring 95, and through the piston rod 93 rocks the arm 90 and rock bar 35 in a counterclockwise direction (Fig. 2) so as to separate the master cam 48 from the follower roller 49.

A fluid pressure system is provided to actuate the various mechanisms of the machine in a definite timed relationship with each other. A reservoir 105 is provided in the base of the machine. Fluid is pumped from reservoir 105 through a pipe 106 by means of a fluid pressure pump 107 which forces fluid through a pipe 108 and 109 to a main control valve 110. Fluid under pressure passing through the pipe 108 also passes through a cycle pilot valve 111 which is operatively connected to shift the main control valve 110 in either direction. A pressure relief valve 112 is operatively connected with the pump 107 so that if the pressure within the system exceeds a predetermined pressure, excess fluid pressure will open the relief valve 112 and return the excess fluid through a pipe 113 into the reservoir 105.

The main control valve 110 is connected by pipes with the various operating mechanisms of the machine. A pipe 115 is connected between the main control valve 110 and the feed cylinder 60. The main control valve 110 is connected by the pipe 98 with the rock bar cylinder 91 and serves to rock the rock bar 35 to an inoperative position after a cam has been ground to the predetermined size and contour and before the table is indexed longitudinally. The cycle pilot valve 111 is connected by pipes 116 and 117 with valve chambers 118 and 119 in opposite ends of the main control valve 110. The valve 111 is arranged so that when shifted in either direction, it will cause the main control valve 110 to shift and thereby control the cycle of operation of the machine.

The main control valve 110 is connected by the pipe 120 with a table reversing valve 121 which in turn is piped and connected with a pilot valve 122. The reverse valve 121 and pilot valve 122 are connected to control the admission of fluid under pressure to the cylinder chambers 30 and 32 of the fluid pressure cylinder 25. A pipe 125 is connected between the main control valve 110 and a slow speed valve 126. The valve 126 is interconnected with the pilot valve 122 and is arranged to slow down the movement of the table 11 to a predetermined slow speed for truing the grinding wheel.

A cycle control mechanism is provided for controlling the cycle of operation of the machine. A cycle counting and control mechanism 128 is mounted above the master cam roller casing 55 and is connected to and actuated by the rocking movement of the rock bar 35. After a predetermined number of rotations of the camshaft 44 in operative relation with the grinding wheel 14, an electric switch 129 is actuated which in turn serves through an electrical circuit to energize a solenoid 130 and thereby shift the cycle pilot valve 111 which in turn shifts the main control valve 110 and changes the direction of movement of fluid under pressure within the system.

The details of the piping arrangement and the electrical cycle control mechanism have not been described, since this is not considered to be a part of the present invention, but have merely been illustrated to show an operative cycle for controlling the grinding of a camshaft. This piping and electrical control is substantially identical to that shown in the copending U. S. patent application Serial No. 56,148 of Herbert A. Silven and Carl G. Flygare filed December 26, 1935, to which reference may be had for a complete description of the piping and electrical circuits shown in Fig. 2.

Operation

Assuming the table 11 to be in its extreme left-hand or loading position, the machine is started in operation by first pushing an electric control button (not shown) to start the rotation of the grinding wheel 14, then pushing a second button (not shown) to start the rotation of the fluid pressure pump 107. Push button 140 is closed to start the rotation of the work driving motor 141. The work piece, such as a camshaft 44, is then loaded in the machine and supported between the headstock center 39 and footstock center 43. A work drive clutch (not shown) is then engaged to start rotation of the master camshaft and the camshaft to be ground. The cycle control push button 143 is then closed to render the mercury switch 129 operative so that the machine is then under the control of the cycle counting mechanism 128. A hand lever 145 is then moved toward the right which serves through connections (not shown) to move the dog lever 150 out of the path of the table stop dog 151. This movement allows the released tension of the spring pressed roller 152 to rock the levers 153 and 154 in a clockwise direction (Fig. 2) which serves to shift the valve 121 toward the left, as viewed in Fig. 2, so that fluid under pressure passing through the pipe 120 into the valve 121 passes outwardly through the pipe 29 into the cylinder chamber 30 to move the piston 26 and table 11 toward the right to bring the first cam 45 on the camshaft 44 into operative grinding relation with the wheel 14.

The longitudinal movement of the table continues until the next dog 151 engages the dog lever 150 which serves to rock the lever 153 from the position shown in Fig. 2, thereby moving the valve stem 121 toward the right to cut off fluid from the pipe 29 and thereby stop the movement of the table 11. When the lever 153 returns to the position illustrated in Fig. 2, a limit switch 155 is closed, serving to energize a relay 156 which in turn energizes the solenoid 157 to withdraw the pawls 158 from engagement with a ratchet wheel 159 so as to allow the released tension of a spring to return the ratchet wheel 159 and the mercury switch 129 to a starting position ready for the control of the next grinding cycle. When lever 145 is shifted toward the left at the start of the grinding cycle, the limit switch 160 is closed and the solenoid 130 is energized to shift the cycle pilot valve 111 upwardly so as to admit fluid under pressure from the pipe 108, through the valve 111 and through a pipe 116 into the chamber 118 to move the main control valve 110 toward the right, as viewed in Fig. 2. This movement of the main control valve 110 serves to cut off the flow of fluid through the pipe 120 to the table reversing valve 121 and serves to admit the flow of fluid under pressure through the pipe 115 and a pipe 165 into a cylinder chamber 166 to move a piston 167 toward the left (Fig. 2) which serves

to rock a lever 168 in a clockwise direction and thereby serves to move the dog lever 150 out of the path of the table dog 151.

At the same time, fluid under pressure passing through the pipe 115 passes through an adjustable throttle valve 88, through a pipe 80, into a cylinder chamber 81 to cause a feeding movement of the master cam follower roller 49. At the same time the main control valve is shifted, as above mentioned, fluid is allowed to exhaust from the cylinder chamber 97 to allow the rock bar 35 to rock so that the master cam 48 engages the master cam roller 49. Rotation of the master cam roller 49 in contact with the master cam 48 serves to rock the camshaft 44 to grind a cam blank 45 to a predetermined contour. Each time the rock bar 35 rocks toward and from the grinding wheel, the cycle control counting device 128 is operated, and after a predetermined number of oscillations of the rock bar 35 serves to rock the mercury switch 129 and thereby break the circuit, which serves to deenergize a relay 170 to break the circuit and deenergize the solenoid 130 which in turn releases the tension of the spring 171 to permit the cycle pilot valve 111 to move into the full line position, as illustrated in Fig. 2. This movement of the cycle pilot valve 111 allows fluid passing through the pipe 109 to enter the valve 111, to pass out through the pipe 117 into a valve chamber 119 at the right-hand end of the main control valve 110 to move the valve toward the left, into the position of the parts illustrated in Fig. 2. This movement of the main control valve 110 again opens the passage of fluid through the pipe 120 to valve 121 and allows it to pass out through the pipe 29 to the cylinder chamber 30 to again index the piston 26 and the table 11 longitudinally to present the next cam 45 into operative relation with the grinding wheel 14.

This cycle of operation is continued until each one of the successive cams 45 on the product camshaft 44 is ground to the desired size and contour. Each time the table 11 is indexed longitudinally to present a new product cam 45 to the grinding wheel 14, the master cam roller 49 is indexed longitudinally by an indexing mechanism, not shown in the present application. This feature is not considered to be part of the present invention and consequently has not been illustrated in detail. For reference to the details of the master cam roller indexing mechanism, reference may be had to the above-mentioned patent to Belden and Silven No. 2,022,178 dated November 26, 1935. When the dog lever 150 is moved out of the path of the dog 151, the released tension of the spring-pressed roller 152 serves to rock the levers 153 and 154 in a clockwise direction.

This movement serves to open the limit switch 155 which in turn serves to deenergize the solenoid 157 and allows the pawl 158 to engage the ratchet wheel 159 so that upon oscillation of the rock bar 35 the pawl 158 may be oscillated to turn the ratchet wheel 159 after each oscillation of the rock bar 35 to control the cycle of grinding on the cam 45. After the cam 45 has rotated through a predetermined number of rotations in contact with the grinding wheel 14 during the grinding operation, the mercury switch 129 is rocked to break the circuit and the breaking of the circuit serves to release the relay 170 to deenergize the solenoid 130, and the released tension of the spring 171 then returns the valve 111 into the position illustrated in Fig. 2. In this position of the valve 111 fluid under pressure from pipe 108

passes through valve 111 and pipe 117 into the chamber 119 at the right-hand end (Fig. 2) of the main control valve 110. This movement of the main control valve 110 serves to allow fluid under pressure to pass through the pipe 120 into the valve 121 which has previously been moved toward the left when the dog lever 150 was withdrawn from the table dog 151 so that fluid under pressure entering the valve 121 passes out through pipe 29 to index the piston 26 and table 11 toward the right. This movement continues until the next dog 151 engages the dog lever 150 to again stop the table movement when the next cam is in operative relation with the grinding wheel.

This cycle of events continues until the last cam 45 on the left-hand end of the camshaft 44 to be ground (Fig. 5) has been ground, after which the table 11 is traversed to a further position toward the right so that the wheel 14 is to the left of the last cam 45 on the shaft 44. During this movement beyond the last cam 45 on the shaft 44, a dog 174 engages a plunger 175 which serves to rock a lever 176 and allows a pin 177 to move freely over a surface 178 and the levers 153 and 176 to take the position shown in Fig. 2. The pin 177 holds the limit switch 160 open. This opening of limit switch 160 serves to deenergize the solenoid 157 and allows the pawl 158 to drop into operative contact with the ratchet wheel 159. At the same time, a table reversing dog 180 engages a table pilot valve lever 181 and rocks it in a clockwise direction (Fig. 2), serving to move the valve 122 toward the left, as viewed in Fig. 2. This movement serves to allow fluid under pressure passing through a pipe 182 into the table pilot valve 122 to pass outwardly therefrom through a pipe 183 into a valve chamber 184 in the left-hand end of the table reverse valve 121. Fluid under pressure entering the reverse valve chamber 184 shifts the valve toward the right, as viewed in Fig. 2, so that the arrow point passes over the high point of the spring-pressed roller 152 and the arrow point serves to hold the reverse valve 121 in a reverse position so that fluid under pressure passing through the pipe 120 into the valve 121 then passes out through the pipe 31 into the cylinder chamber 32 of the table operating cylinder 25 to cause the table 11 to move rapidly through an idle stroke toward the left (Fig. 2).

This movement serves to return the table 11 to its initial or starting position. When the table 11 approaches the left-hand end of its movement, a truing dog on the table 11 engages the roller 186 and depresses the same, which serves to shift the truing speed valve 126 toward the right (Fig. 2) so that fluid under pressure exhausting from the table cylinder 25 passes through a V-port 187 to throttle the exhaust thereof and to regulate the speed of movement of the table 11 while a truing tool (not shown) mounted on the table 11 passes across the face of the wheel 14, whereupon a depending projection of the truing dog engages the lever 181 to rock it in a counterclockwise direction to move the valve 122 toward the right (Fig. 2), serving to admit fluid under pressure entering through pipe 182 into the valve 122, out through a pipe 188, into a valve chamber 189 at the right-hand end of the table reversing valve 121. This movement serves to shift the table reversing valve 121 into the position illustrated in Fig. 2, so that the valve is in position ready to start the

next grinding cycle after the finish ground camshaft 44 has been removed and replaced with a new camshaft to be ground. When the reverse valve 121 shifts into the position above described, the table 11 starts its return stroke toward the right to pass the diamond across the face of the wheel a second time and continues this motion until the dog lever 150 engages the table stop dog 151 which stops the table 11 just before the first cam 45 moves into operative relation with the grinding wheel 14. The machine is then in a stopped position and the ground camshaft 44 may be readily removed and replaced with a fresh camshaft to be ground.

During the wheel truing operation the headstock motor 141 is stopped by means of the adjustably mounted table dog 190 to permit the removal of the finish ground camshaft 44 from the machine during the truing operation. Dog 190 slides over and depresses a rod 191 of a limit switch 192 which breaks the circuit to deenergize a relay 193 which stops the headstock motor 141. As the table 11 reciprocates during the truing operation, the table dog 190 slides over the rod 191 and upon completion of the truing operation, the table 11 moves to the table stop dog 151 at the end of the grinding cycle, dog 190 still maintaining contact with the rod 191. Upon starting of the grinding cycle, the dog 190 will come out of contact with the rod 191 and close the limit switch 192 to start the headstock motor 141 before the first cam 45 comes into operative relationship with the grinding wheel 14.

It will thus be seen that there has been provided by this invention apparatus in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:—

1. In a camshaft grinding machine, a rotatable grinding wheel, a longitudinally movable rock bar, a rotatable master camshaft on said bar having a plurality of master cams thereon, a rotatable work support on said bar which is arranged to support a camshaft in axial alignment with said master camshaft, means synchronously to rotate said camshaft and master camshaft, a rotatable master cam follower roller associated with said master cams which is arranged to cause a transverse movement between the grinding wheel and camshaft to grind a predetermined contour on a cam blank, and means to move said master cam roller transversely during the grinding operation to produce a relative approaching movement between the camshaft support and grinding wheel to grind the cam blank to a predetermined size.

2. In a camshaft grinding machine, a rotatable grinding wheel, a longitudinally movable rock bar, a rotatable master camshaft on said bar having a plurality of master cams thereon, a rotatable work support on said bar which is arranged to support a camshaft in axial alignment with said master camshaft, means synchronously to rotate said camshaft and master camshaft, a rotatable master cam follower roller associated with said master cams which is arranged to cause a transverse movement between

the grinding wheel and camshaft to grind a predetermined contour on a cam blank, means including a rotatable cam to move said master cam roller transversely during the grinding operation, and means to actuate said cam to move said roller and thereby produce a relative approaching movement between the camshaft support and grinding wheel to grind a cam blank to a predetermined size.

3. In a camshaft grinding machine, a rotatable grinding wheel, a longitudinally movable rock bar, a rotatable master camshaft on said bar having a plurality of master cams thereon, a rotatable work support on said bar which is arranged to support a camshaft in axial alignment with said master camshaft, means synchronously to rotate said camshaft and master camshaft, a rotatable master cam follower roller associated with said master cams which is arranged to cause a transverse movement between the grinding wheel and camshaft to grind a predetermined contour on a cam blank, means including a rotatable cam and a follower to move the master cam roller transversely during the grinding operation, and means including a fluid pressure piston and cylinder operatively connected to rotate said cam to produce a relative infeeding movement between the camshaft support and grinding wheel to grind a cam blank to a predetermined size.

4. In a camshaft grinding machine, a rotatable grinding wheel, a longitudinally movable rock bar, a rotatable master camshaft on said bar having a plurality of master cams thereon, a rotatable work support on said bar which is arranged to support a camshaft in axial alignment with said master camshaft, means synchronously to rotate said camshaft and master camshaft, a rotatable master cam follower roller associated with said master cams which is arranged to cause a transverse movement between the grinding wheel and camshaft to grind a predetermined contour on a cam blank, a transversely movable slide which is arranged rotatably to support the master cam roller, and means to move said slide transversely during the grinding operation to produce a relative feeding movement between the camshaft support and grinding wheel to grind a cam blank to a predetermined size.

5. In a camshaft grinding machine, a rotatable grinding wheel, a longitudinally movable rock bar, a rotatable master camshaft on said bar having a plurality of master cams thereon, a rotatable work support on said bar which is arranged to support a camshaft in axial alignment with said master camshaft, means synchronously to rotate said camshaft and master camshaft, a rotatable master cam follower roller associated with said master cams which is arranged to cause a transverse movement between the grinding wheel and camshaft to grind a predetermined contour on a cam blank, a transversely movable slide arranged rotatably to support the master cam roller, a rotatable cam and a follower to cause a transverse movement of said slide and roller, and means to rotate said cam to produce an infeeding movement of said slide to grind a cam blank to a predetermined size.

6. In a camshaft grinding machine, a rotatable grinding wheel, a longitudinally movable rock bar, a rotatable master camshaft on said bar having a plurality of master cams thereon, a rotatable work support on said bar which is arranged to support a camshaft in axial alignment with said master camshaft, means syn-

chronously to rotate said camshaft and master camshaft, a rotatable master cam follower roller associated with said master cams which is arranged to cause a transverse movement between the grinding wheel and camshaft to grind a pre-determined contour on a cam blank, a transversely movable slide rotatably to support said master cam roller, means including a rotatable cam and a follower to move said slide transversely, and means including a fluid pressure piston and cylinder operatively connected to rotate said cam to cause a transverse movement of said slide and roller and thereby to produce a relative approaching feed between the camshaft support and grinding wheel.

7. In a cam grinding machine having a rotatable grinding wheel and a transversely movable wheel slide, a longitudinally movable work table and a rock bar thereon, a master camshaft on said rock bar, a rotatable master cam follower, a transversely movable slide to support said follower, a separate fluid motor for said work table, rock bar and master cam roller slide, a main control valve in control of said motors, and a cycle control mechanism actuated in timed relation with the movement of said rock bar to actuate the main control valve.

8. In a cam grinding machine having a rotatable grinding wheel and a transversely movable wheel slide, a longitudinally movable work table and a rock bar thereon, a master camshaft on said rock bar, a rotatable master cam follower, a transversely movable slide to support said follower, a separate fluid motor for said work table, rock bar and master cam roller slide, a main control valve in control of said motors, a pilot valve to actuate said main control valve, an electric solenoid to shift said pilot valve, and a cycle control mechanism including an electric switch

actuated in timed relation with the rocking movement of said bar during grinding to energize said solenoid.

9. In a cam grinding machine having a rotatable grinding wheel and a transversely movable wheel slide, a longitudinally movable work table and a rock bar thereon, a master camshaft on said rock bar, a rotatable master cam follower, a transversely movable slide to support said follower, a separate fluid motor for said work table, rock bar and master cam roller slide, a main control valve in control of all of said motors, a pilot valve to actuate said main control valve, a solenoid to shift said pilot valve, and a cycle control mechanism including a pawl and ratchet actuated by and in timed relation with the rocking movement of said bar during grinding to control an electric switch so as to energize said solenoid and thereby control the grinding cycle.

10. In a cam grinding machine having a pivotally mounted camshaft support and master cams and follower to control the rocking movement of said support, a longitudinally movable table to support said camshaft support, a transversely movable rotatable grinding wheel and slide, a transversely movable slide supporting said follower, said camshaft support, work table and follower slide each being operated by a separate fluid motor, a main control valve in control of all of said motors, a cycle control device including a pawl and ratchet actuated electric switch, connections between said pivotally mounted camshaft support and pawl to actuate the same in timed relation with the rocking of said camshaft support, and electrically controlled mechanism operated by said switch to rock said bar to an inoperative position after a predetermined grinding operation has been completed.

CLARENCE J. GREEN.