Dec. 23, 1941.

C. J. ASTROWSKI

2,267,391

ABRADING MACHINE

Filed Aug. 3, 1940

Fig. 1.

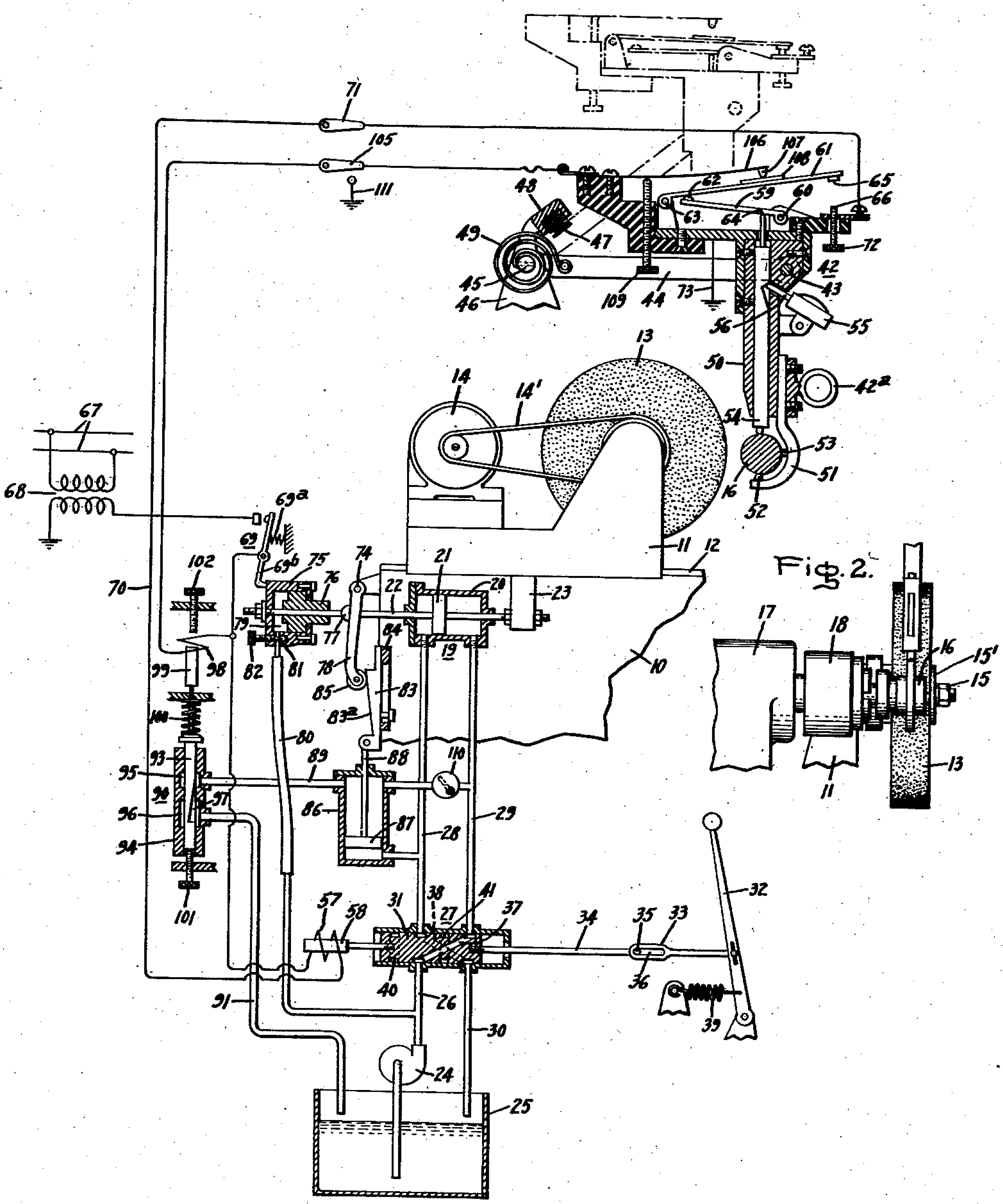

Fig. 2.

Inventor:
Charles J. Astrowski,
by Harry E. Dunham
His Attorney.

Patented Dec. 23, 1941 2,267,391

UNITED STATES PATENT OFFICE

2,267,391

ABRADING MACHINE

Charles J. Astrowski, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application August 3, 1940, Serial No. 350,178

15 Claims. (Cl. 51—165)

My invention relates to abrading machines and particularly to automatic precision abrading machines for finishing work pieces uniformly within extremely close tolerances.

Automatic abrading or grinding machines are commonly provided with gauging or calipering devices arranged to actuate a mechanism for terminating the grinding operation when the work has been reduced to a predetermined size. It has been found extremely difficult to construct an automatic grinding machine in which work pieces may be finished uniformly within close tolerances. This difficulty is due in part to the effect of the momentum of the moving parts of the machine and the inability of the control device to compensate for the continued movement of the grinding wheel and carriage after initiation of the stopping operation. Further difficulties arise because of lost motion in the machine and the flexibility of certain parts of the control mechanism. Extremely high accuracy of the gauging or calipering device used to determine the size of the work becomes ineffective if the automatic control is unable to stop the grinding operation within the desired limits of size of the finished work.

It is an object of my invention to provide an improved abrading machine including a mechanism for effecting an extremely low rate of relative movement between the abrading tool and the work.

Another object of my invention is to provide an automatic abrading machine including an improved device for controlling the abrading operation to finish work pieces uniformly within extremely close limits of accuracy.

Another object of my invention is to provide an automatic abrading machine having an improved fluid operated driving mechanism which shall make possible the finishing of work pieces within extremely small tolerances.

A further object of my invention is to provide an improved automatic abrading machine including a control device arranged to minimize any effect of the continued operation of the abrading tool and driving mechanism after the initiation of the stopping of the abrading operation.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 is a diagrammatic side elevation view of an external grinding machine embodying my invention, the conventional work holder including a head-stock and driving mechanism being omitted to avoid complication of the drawing; and Fig. 2 is a front view of a portion of the machine of Fig. 1 showing the work in position in the work holder.

The grinding machine illustrated in the drawing is a type in general use and comprises a base on which are mounted a work holder and a driving mechanism for rotating the work and a transverse wheel slide on which are mounted a grinding wheel and a motor for driving the wheel. Suitable power mechanism is provided for rotating the work and for moving the wheel toward and away from the work to effect the grinding operation. In the machine illustrated, the wheel slide is actuated by hydraulic operators or fluid motors. The forward operation of the grinding wheel toward the work is started manually. A suitable work measuring or calipering gauge is maintained in position on the work during grinding and is provided with contacts in an electrical circuit for controlling the operation of the fluid motors. The control is such that after the work has been reduced to a first predetermined size, the gauging mechanism operates to reduce the rate of feed of the wheel toward the work for a finishing cut. After the work has been finished within the predetermined limits of size, the control terminates the grinding operation. An arrangement is provided so that the feeding of the rotating grinding wheel toward the work during the finishing operation is at such a low rate that the forward movement of the wheel and carriage can be terminated and the carriage reversed before the continued rotation of the wheel can reduce the work beyond the predetermined limits of tolerance. An extremely low rate of feeding of the wheel slide is obtained by providing a stop to limit the forward movement of the slide which can be produced by operation of its driving motor. Movement of the stop is controlled by a cam which is designed so that it may be moved through a wide range while allowing only a very small movement of the stop. The cam preferably is driven by a fluid motor supplied by fluid under pressure from the same source that supplies the motor for driving the wheel slide. The control of the rate of movement of the cam can then be effected by a suitable valve for changing the rate of flow of fluid for actuating the cam driving motor.

Referring now to the drawing, the abrading machine shown in Fig. 1 comprises a base 10 on which is mounted a wheel carriage or slide 11 which is arranged to slide transversely of the base 10 on a plurality of guides 12 of V-shaped cross-section in a manner well known in the art. On the wheel carriage 11 are mounted a grinding wheel 13 and a motor 14 connected to drive the wheel through a belt 14'. The work piece to be ground is mounted in a suitable work holder for rotation on a longitudinal axis which is normally parallel to the axis of the wheel 13. The work piece is indicated at 16 in Fig. 1, and in Fig. 2 I have shown the work mounted in a work holder comprising a head-stock 17 and a suitable chuck 18 for gripping the work. The head-stock 17 may be arranged to slide longitudinally of the base 10 on an axis at right angles to the guides 12. As shown in Fig. 2, the grinding wheel 13 may be removed by loosening a suitable nut 15 and removing the nut and a collar 15'.

The arrangement illustrated in which the wheel is moved toward the work is one commonly employed. However, it is obvious that any suitable arrangement for moving the wheel and the work holder relatively to one another so that the wheel can be moved toward and away from the work might be employed; for example, in some cases it might be found desirable to hold the wheel stationary and to move the work. Obviously the same power and control devices may be employed for either arrangement.

In order to finish the work within close tolerances, it is desirable that the abrading machine be arranged to feed the wheel toward the work at a very low rate of speed, and I prefer to employ a fluid pressure or hydraulic motor as the power device in order to obtain smooth operation and accurate and flexible control. In the arrangement shown in the drawing, a fluid motor 19 comprising a cylinder 20 and a piston 21 is arranged to drive a power transmitting shaft 22 which is connected to the wheel slide 11 through a suitable lug or driving connection 23. Power for driving the motor 19 is provided by a fluid pressure pump 24 arranged to pump oil or other suitable liquid from a tank 25 through a connection 26 and a control or reversing valve 27 either to a forward feed line 28 or to a return feed line 29, the fluid returned from the motor 19 flowing back to the tank 25 through one or the other of the lines 28 and 29, the valve 27 and a connection 30. The valve 27 is provided with a slide 31 arranged to be actuated by a manually operable handle 32 connected to the slide through a lost motion link 33 and a rod 34, the rod 34 having a pin 35 fitting in a slot 36 in the link 33. The slide 31 has been shown in its position for driving the motor 19 to move the wheel away from the work. When the valve is in the position shown, the fluid from the pump 24 flows through a diagonal cross duct 37 in the slide and thence through the return feed line 29 to the right-hand side of the piston 21, thereby forcing the piston to the right. Any oil or fluid on the left-hand side of the piston is forced out through the forward feed line 28 to the valve 27 and thence through a diagonal cross duct 38 to the connection 30 and back to the tank 25. When it is desired to operate the motor 19 to move the slide 11 toward the work, the handle 32 is moved to the right and pulls the slide 27 to its right-hand position. Upon its release the handle 32 is returned to the position shown by a suitable spring 39. When the slide 31 is in its right-hand position, the connection 26 from the pump 24 is maintained in direct communication with the forward feed line 28 through a suitable slot 40 and the return feed line 29 is in direct communication with the connection 30 through a slot 41. The slots 40 and 41 are in the form of annular grooves around the slide 31. When the slide is in its right-hand position, fluid is forced by the pump 24 to the left-hand side of the piston 21 through the forward line 28 and drives the motor 19 to move the wheel slide toward the work; fluid forced out of the right-hand side of the piston 21 is returned to the tank 25 through the line 29, the slot 41, and the connection 30.

In order to determine the size of the work piece as it is being ground, I provide a suitable gauge or calipering device 42. The gauge 42 is pivotally mounted at 43 on an arm 44, the arm 44 being pivoted at 45 to a stationary member 46, and a handle 42a is provided for moving the gauge about its pivot 45. This pivotal mounting of the gauge is provided in order that the gauge may be moved out of its position adjacent the work so that it will not be in the way when the work pieces are being placed in or removed from the work holder. The retracted position of the gauge is indicated by dotted lines, the arm 44 having been pivoted upwardly in a counter-clockwise direction. A suitable spring 47 mounted in a stop 48 provides a buffer to prevent shock when the arm 44 is lifted; and a spiral spring 49 is arranged to hold the gauge in its raised position. The gauge comprises a head 50 on which is mounted an arm 51 having two contacts 52 and 53 for positioning the gauge against the work and a sliding contact or feeler 54 arranged to slide in the head 50 and indicate the size of the work. An indicating dial or gauge 55 may be connected on the head 50 and engaging the feeler 54 through a rod 56 to indicate the diameter of the work. The gauge 42 is arranged to actuate electrical contacts in a circuit for controlling the operation of the abrading machine to terminate the grinding operation whenever the work has been finished to a predetermined size. Whenever the work has been finished to a predetermined size, a circuit is energized to actuate a solenoid 57 having an armature or plunger 58 connected to the slide 31 of the valve 27. Energization of the solenoid 57 pulls the slide 31 to its left-hand position and thereby reverses the motor 19 and withdraws the wheel slide 11 to separate the wheel and the work. In order that the control arrangement shall be sensitive to slight variations in the size of the work, I provide a high ratio leverage system for actuating the control contacts by means of the feeler 54. This lever system comprises an arm 59 pivoted to the gauge head at 60 and arranged to engage a second arm 61 at 62, the arm 61 being pivotally mounted on the frame of the gauge at 63. It will be obvious that with the arrangement of the pivoted arms 59 and 61 a very slight movement of the feeler 54, which engages the arm 59 at 64, will effect a considerable movement of the end of the arm 61. An electrical contact 65 is mounted on the end of the arm 61 and is arranged to engage an adjustable stationary contact 66 to close the circuit of the solenoid 57. Power for energizing the circuit is received from an alternating current source 67 across which is connected the primary winding of a transformer 68. One side of the secondary of the transformer 68 is grounded and the other side is connected to the solenoid 57 through a switch 69. The switch 69 is biased to its closed position by a spring 69a and is closed whenever the grinding machine is in operation, it being held open by an extended arm 69b contacting a member on the wheel slide only when the slide is near its left-hand position as shown in the drawing. From the solenoid 57 the circuit extends through a line 70 and a manual switch 71 to the stationary contact 66 and thence through the movable contact 65 and the arm 61 to the frame of the gauge which is grounded by a connection 73. The switch 71 may be used to cut out the automatic stopping of the machine when manual operation is desired. From the foregoing, it will be seen that when the work has been ground to a predetermined size, the contact 65 will engage the fixed contact 66 and complete the electrical circuit for energizing the solenoid 57 thereby pulling the valve slide 31 to its left-hand position and withdrawing the wheel slide to terminate the grinding operation. The position of the point of engagement between the contacts 65 and 66 may be selected by operation of a thumb screw 72 which raises and lowers the contact 66. The adjustment of the thumb screw 72 determines the size to which the work is finished when the grinding operation is terminated.

With the machine in the position shown in Fig. 1, the grinding operation is started by pushing the handle 32 to the right to operate the motor 19 and move the wheel toward the work; the force transmitting rod 22 moves to the right and a dash pot 75 secured to the end of the rod moves to the right with the rod until a plunger 76 of the dash pot engages a stop 77 mounted on an arm 78 pivoted on base 10 at 74. When the plunger 76 has engaged the stop, the rate of forward movement of the wheel toward the work is decreased by fluid pressure against the plunger 76. When the dash pot 75 is forced to the right with respect to the plunger 76 oil within a chamber 79 is forced out through a conduit 80 against the pressure of the pump 24, the outlet of the pump being connected directly with the chamber 79 through a restricted opening 81. The size of the opening 81 may be adjusted by a thumb screw 82. Whenever sufficient fluid has been forced out of the chamber 79 to permit engagement of the inner end of the plunger 76 with the closed end of the dash pot 75, further movement of the rod 22 to the right is prevented, the movement of the motor 19 then being restricted by the stop 77. I have found that by providing an auxiliary device for controlling movement of the stop 77 to modify the operation of the motor 19, very accurate control of the movement of the wheel toward the work can be effected; furthermore, by providing a suitable device such as a cam, it is possible to control the machine so accurately that the effects of the momentum of the carriage 11 and of the wheel 13 cannot reduce the work below a predetermined limit of size after the initiation of the stopping operation. In the arrangement illustrated, I have provided an elongated wedge-shaped cam 83 slidably mounted for longitudinal movement in a fixture 84 secured to the base 10. The arm 78 is provided with a cam follower 85 which engages an inclined surface 83a of the cam. It will be understood that after sufficient fluid has been forced out of the chamber 79 of the dash pot 75 upon operation of the motor 19, further movement of the motor 19 will be dependent solely upon movement of the cam 83. By suitable control of the upward movement of the cam 83, which affords movement of the stop 77 by allowing the follower 85 to roll down the slide 83a of the cam, it is possible to effect a very low rate of movement of the wheel toward the work. In order to obtain very accurate control of the movement of the cam 83 and to obtain variable speed of the cam, I prefer to employ a hydraulic motor 86 having a piston 87 connected to drive the cam 83 through a rod 88. The motor 86 is provided with fluid under pressure from the pump 24 under control of the valve 27. The motors 19 and 86 are, therefore, operated simultaneously. When the machine is started by moving the slide 31 of the valve 27 to the right, fluid under pressure enters the motor 86 below the piston 87 from the forward feed line 28 and moves the cam upward, the fluid from the upper side of the piston 87 being returned to the tank 25 through a connection 89, a valve 90, and a drain conduit 91. Although the motors 19 and 86 operate to move the carriage 11 and the cam 83 forward simultaneously, the cam 83 is not effective to control the movement of the carriage until the plunger 76 of the dash pot has engaged the stop 77 and the cam is not completely effective to control the movement of the carriage until the fluid has been forced from the chamber 79 of the dash pot. By designing the cam surface 83a so that the cam can be moved longitudinally through a relatively great distance to effect a very small movement of the cam follower 85, it is possible to attain a very high degree of accuracy in the grinding operation since a very low rate of movement of the wheel carriage may be attained and since the rate of movement is very uniform. A further reduction in the movement of the carriage 11 for a given movement of the cam follower 85 is obtained by the leverage of the arm 78. It will be noted that the cam follower 85 is at the end of the long arm of the lever, while the stop 77 is on the short arm of the lever, the movement of the stop 77 being less than the movement of the cam follower 85 in accordance with the ratio of the short arm of the lever to the long arm thereof. The valve 90 is arranged to control the rate of discharge of fluid from the cam driving motor 86 and therefore controls the rate of flow of the fluid into the motor which determines the motor speed. I provide the valve 90 in order to obtain a high degree of accuracy of the control of the cam and also to provide two speeds of operation, one speed for the initial cut or rough grinding operation, and a lower speed for the finishing operation. The valve 90 comprises a slide 93 mounted in a valve body 94 having upper and lower chambers 95 and 96, respectively, separated by a suitable partition, the chamber 95 being in communication with the upper chamber of the motor 86 through the connection 89, and the chamber 96 being in communication with the tank 25 through the drain conduit 91. The slide 93 is provided with a tapered slot 97 which provides a variable opening between the chambers 95 and 96, the size of the opening depending upon the position of the slide 93 in the valve body 94. In the bottom position of the slide 93 as illustrated, the opening between the chambers 95 and 96 is restricted, and when the slide is raised to its upper position the opening is relatively free. The slide is arranged to be raised to its upper position by a solenoid 98 having an armature 99 for raising the slide 93 in opposition to a spring 100. The lower position of the slide 93 which controls the lower speed for fine feed may be adjusted by a thumb screw 101, and the upper position of a slide which determines the higher speed for coarse feed may be adjusted by a thumb screw 102.

The position of the valve 90 to provide the coarse and fine feeds is controlled by the gauge mechanism 42 which is provided with a set of contacts for controlling the circuit of the solenoid 98. During the operation of the machine, as soon as the motor 19 has moved the dash pot 75 to the right, the switch 69 is closed by its biasing spring 69a which is effective as soon as the dash pot 75 releases the arm 69b. The closing of the switch 69 energizes the solenoid 98 by connecting it to the secondary of the transformer 67 and through a manual switch 105 and a spring contact arm 106 on the gauge with the return circuit or ground through the arm 61. The spring arm 106 has a contact 107 which is maintained in engagement with a contact 108 on the arm 61 as long as the work piece is above a predetermined size and the valve 90 is therefore actuated by the solenoid 98 to maintain the slide 93 in its upper position thereby advancing the cam 83 at its higher rate of speed to operate the wheel 13 and reduce the work at a relatively high rate. Whenever the work has been reduced to the above-mentioned predetermined size, the downward movement of the arm 61 causes a separation of the contacts 107 and 108, the point of separation depending upon the adjustment of a thumb screw 109 the upper end of which provides a stop limiting movement of the arm 106. The opening of the contacts 107 and 108 deenergizes the solenoid 98 and causes the valve slide 93 to move to its lower position thereby restricting the flow of fluid from the motor 86 which then moves the cam at a greatly reduced rate of speed. The wheel slide 11 then advances very slowly to make the finishing cut until the work is reduced to a predetermined size within the permissible limits of tolerance and contact 65 engages the contact 66; this energizes the solenoid 57 to move the valve slide 31 to the left and reverse the cam and wheel slide motors thereby terminating the grinding operation. Fluid from the pump 24 for reversing the motor 86 is supplied from the return feed line 29 through a check valve 110, the valve 90 restricting the flow through connection 89 so that the fluid pressure is effective to lower the piston 87. The switch 105 may be used to cut out the contacts 107 and 108 by grounding the switch on a connection 111 when the fine feed control is not required or when it is to be controlled manually.

I have found that by a suitable design of the surface 83a of the cam 83, it is possible to operate a grinding machine to finish work pieces uniformly within an extremely high degree of accuracy. For example, one hydraulically powered machine which was tested was provided with a gauging mechanism of the type illustrated on the drawing having a leverage ratio of 180 to 1 between the contact 65 and the feeler 54. The machine was further provided with a lever corresponding to the lever 78 having a ratio of 3 to 1 between the cam follower 85 and the stop 77. The surface of the cam 83 was provided with a slope of .008 inch per inch of length. Work pieces finished on this machine and tested by means of an electrical gauge were found to have been finished uniformly within one half of one ten thousandth (.00005) of an inch.

During the operation of the abrading machine illustrated, the machine is initially in the position shown with the gauge 42 in its raised position as indicated by the dotted lines and the motor 14 and the motor (not shown) for the pump 24 are operated continuously. A work piece 16 is then placed in the chuck 18 and the gauge is lowered in position so that the contacts 52 and 53 and the feeler 54 engage the work. The head-stock motor for rotating the work is then started and the handle 32 is moved to the right to place the slide 31 in its forward operating position, the handle 32 when released moving back to its position as shown by the action of spring 39. The pump 24 then supplies fluid under pressure to produce forward motion of the motors 19 and 86, the piston 21 moving to the right and driving the wheel slide forward until the plunger 76 of the dash pot 75 engages the stop 77. The rate of movement of the wheel slide is then slowed to a rate depending upon the size of the restriction 81 connecting the dash pot and the fluid supply. As soon as the dash pot 75 has moved a short distance to the right, the spring 69a closes the switch 69 and energizes the solenoid 98 to lift the valve slide 93 and afford relatively free flow of fluid through the valve 90 so that the motor 86 may be actuated at its higher speed. The cam 83 moves upwardly and the stop 77 is moved to the right at the higher rate dependent upon the high speed movement of the cam 83. The grinding wheel moves forward into the work and as soon as the work has been reduced to a predetermined size, which is the limiting size for the rough cut, the contacts 107 and 108 separate and break the circuit of the solenoid 98; thereupon the slide 93 moves to its bottom position and restricts the flow of fluid through the valve 90 thereby reducing the speed of the motor 86 to its low speed and moving the cam and carriage 11 at minimum speed for the finish grinding cut. As soon as the work has been reduced to a second predetermined size which is within the permissible limits of accuracy, the contact 65 engages the contact 66 and thereby energizes the solenoid 57; this moves the slide 31 of the valve 27 to its left-hand position to reverse the motors and withdraw the wheel from the work and return the cam 83 to its position as shown in the drawing. When the work has been finished, the gauge 42 is removed from the work and placed in its raised position manually by means of handle 42a.

By designing the slope 83a of the cam 83 so that the cam is movable through a relatively wide range to afford a small range of movement of the cam follower 85 by operation of the motor 19, it is possible to insure separation of the grinding wheel and the work before the momentum of the slide 11 and the continued operation of the wheel can reduce the work below the predetermined permissible minimum limit of size. This feature of the operation which minimizes overgrinding due to the momentum of the wheel and its slide also minimizes inaccuracies due to irregularities or lost motion in any of the moving parts of the machine or its control and, thereby, makes possible the finishing of work pieces in large numbers with great uniformity and within very close limits of accuracy.

It will readily be apparent from the foregoing that I have provided a simple and effective arrangement for insuring accurate and uniform finishing of work pieces within very small limits or tolerances; and further that the high degree of accuracy is effected with a device of simple and rugged construction. Although I have shown a particular embodiment of my invention in connection with an external grinding machine, other applications will readily be apparent to those skilled in the art. I do not, therefore, desire my invention to be limited to the particular construction shown and described, and I intend in the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means for effecting such relative movement, means including a cam and arranged to provide a stop for said power means for determining the rate of movement of said tool toward the work, and means dependent upon the reduction of the work to a predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being movable through a wide range to afford a small movement of said tool toward the work whereby any further reduction of the work caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

2. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means for effecting such relative movement, means including a cam and arranged to provide a stop for determining the rate of movement of said tool toward the work, means dependent upon a reduction of the work to a first predetermined size for reducing the rate of movement of said cam, and means dependent upon the further reduction of the work to a second predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being movable through a wide range to afford a small movement of said tool toward the work whereby any reduction of the work below said second predetermined size caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

3. An abrading machine including a work holder and an abrading tool, power means for moving said work holder and said tool with respect to one another into and out of a working range, a movable stop arranged to cooperate with said power means to restrict the movement of said tool and said holder toward said working range, means including a cam arranged to afford movement of said stop by said power means for determining the rate of movement of said tool and said work holder with respect to one another within said working range, and means dependent upon the reduction of the work to a predetermined size for actuating said power means to move said tool and said holder apart with respect to one another and out of said working range.

4. An abrading machine including a work holder and an abrading tool, power means including a member for moving said work holder and said tool with respect to one another into and out of a working range, a movable stop arranged to cooperate with said member to restrict movement of said power means in a direction to move said tool and said holder toward said working range, means including a cam arranged to determine the rate of movement of said stop when said member is moving said tool and said holder toward said working range and means dependent upon the reduction of the work to a predetermined size for actuating said power means to move said tool and said holder apart in respect to one another and out of said working range.

5. An abrading machine including a work holder and an abrading tool, power means for moving said work holder and said tool with respect to one another into and out of a working range, a movable stop arranged to cooperate with said power means to restrict the movement of said tool and said holder toward said working range, means including a cam arranged to afford movement of said stop at a plurality of different speeds for determining the rate of movement of said tool and said work holder with respect to one another by operation of said power means within said working range, means for effecting simultaneous operation of said power means and of said cam, means dependent upon a reduction of the work to a first predetermined size for reducing the rate of movement of said cam, and means dependent upon a further reduction of the work to a second predetermined size for actuating said power means to move said tool and said holder apart with respect to one another and out of said working range.

6. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means for effecting such relative movement, means including a longitudinally movable wedge-shaped cam and arranged to provide a stop for said power means for determining the rate of movement of said tool toward the work, and means dependent upon the reduction of the work to a predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being longitudinally movable through a wide range to effect a relatively small movement of said tool toward the work whereby any further reduction of the work caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

7. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means for effecting such relative movement, means including a longitudinally movable wedge-shaped cam and arranged to provide a stop for said power means for determining the rate of movement of said tool toward the work, means dependent upon the reduction of the work to a first predetermined size for reducing the rate of longitudinal movement of said cam, and means dependent upon the further reduction of the work to a second predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being longitudinally movable through a wide range to afford a relatively small movement of said tool toward the work whereby any reduction of the work below said second predetermined size caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

8. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means operable by fluid pressure for effecting such relative movement, means including a cam and arranged to provide a stop for said power means for determining the rate

of movement of said tool toward the work, fluid pressure operated means for actuating said cam, means for supplying fluid under pressure to said power means and to said means for operating said cam, and means dependent upon a reduction of the work to a predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being movable through a wide range to afford a relatively small movement of said tool toward the work whereby any further reduction of the work caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

9. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means for effecting such relative movement, means including a cam and arranged to provide a stop for said power means for determining the rate of movement of said tool toward said work, fluid pressure operated means for operating said cam, means for supplying fluid under pressure to said means for actuating said cam, means arranged to restrict the flow of fluid through said cam operating means for reducing the rate of movement of said cam, means dependent upon the reduction of the work to a first predetermined size for actuating said last mentioned means to reduce the rate of movement of said cam, and means dependent upon a further reduction of the work to a second predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being movable through a wide range to afford a relatively small movement of said tool toward the work whereby any further reduction of the work caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

10. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means operable by fluid pressure for effecting such relative movement, means including a cam and arranged to provide a stop for determining the rate of movement of said tool toward the work, means operable by fluid pressure for actuating said cam, means for supplying fluid under pressure to said power means and to said means for actuating said cam, means arranged to restrict the flow of fluid in said means for actuating said cam for changing the speed of operation of said cam, means dependent upon the reduction of the work to a first predetermined size for actuating said last mentioned means to reduce the rate of movement of said cam, and means dependent upon the further reduction of the work to a second predetermined size for stopping the supply of fluid under pressure to said power means and to said cam actuating means to stop the movement of said tool toward the work, said cam being movable through a wide range to afford a relatively small movement of said tool toward the work whereby any reduction of the work below said second predetermined size caused by operation of said tool after initiation of the stopping of said fluid supply means will lie within a predetermined permissible working tolerance.

11. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means operable by fluid pressure for effecting such relative movement, means including a cam arranged to provide a stop for said power means for determining the rate of movement of said tool toward the work, reversible means for supplying fluid under pressure to said power means, and means dependent upon reduction of the work to a predetermined size for actuating said last mentioned means to reverse the operation of said power means and to move said tool away from the work, said cam being movable through a wide range to afford a relatively small movement of said tool toward the work whereby any further reduction of the work caused by operation of said tool after initiation of the reversing of said power means will lie within a predetermined permissible working tolerance.

12. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means for effecting such relative movement, means including a cam and arranged to provide a stop for said power means for determining the rate of movement of said tool toward said work, fluid pressure operated means for actuating said cam, means for supplying fluid under pressure to said pressure operated means for actuating said cam, means including a two-position valve for controlling the rate of flow of fluid through said cam actuating means for determining the rate of movement of said cam, means for initially positioning said valve to effect a predetermined rate of movement of said cam, means dependent upon the reduction of the work to a first predetermined size for positioning said valve to effect a reduced rate of movement of said cam, and means dependent upon a further reduction of the work to a second predetermined size for stopping the operation of said power means to move said tool toward the work, said cam being movable through a wide range to afford a relatively small movement of said tool toward the work whereby any further reduction of the work caused by operation of said tool after initiation of the stopping of said power means will lie within a predetermined permissible working tolerance.

13. An abrading machine comprising a work holder and an abrading tool which are relatively movable to feed the tool toward and away from the work, power means including a power transmitting member and a fluid pressure motor for effecting such relative movement, a stop arranged adjacent said power transmitting member and an abutment on said member adapted to engage said stop for restricting the movement of said member to move said tool toward the work, means including a cam arranged to afford movement of said stop to determine the rate of movement of said tool toward the work, a fluid pressure motor for moving said cam, means including a valve operable in one position to supply fluid under pressure for forward movement of said motors and operable in another position to supply fluid under pressure for the return movement of said motors, and means dependent upon the reduction of the work to a predetermined size for operating said valve to effect said return movement of said motors, said cam being movable through a wide range to effect a relatively small movement of the tool toward the work whereby any further reduction of the work caused by operation of said tool after actuation of said valve toward its reversed position will lie within a predetermined permissible working tolerance.

14. An abrading machine comprising a work support and a wheel slide, an abrading wheel rotatably mounted on said slide, means including a motor operable by fluid pressure and a power transmitting member connecting said motor and said slide for moving said wheel toward and away from the work, a movable stop arranged to engage said power transmitting member for restricting the movement of said wheel toward the work, means including a cam having an inclined surface for affording movement of said stop to determine the rate of movement of said wheel toward the work, a motor operable by fluid pressure for moving said cam, means for supplying fluid under pressure simultaneously to both of said motors, means including a valve for reversing the direction of fluid flow to said motors for reversing said motors, and means including a gauge arranged to determine the size of the work and dependent upon the reduction of the work to a predetermined size for actuating said valve to reverse said motors.

15. An abrading machine comprising a work support and a wheel slide, an abrading wheel rotatably mounted on said slide, means including a motor operable by fluid pressure and a power transmitting member connecting said motor and said slide for moving said wheel toward and away from the work, a movable stop arranged to engage said power transmitting member for restricting the movement of said wheel toward the work, means including a cam having an inclined surface for affording movement of said stop to determine the rate of movement of said wheel toward the work, a motor operable by fluid pressure for moving said cam, means for supplying fluid under pressure simultaneously to both of said motors, means including a valve for reversing the direction of fluid flow to said motors to reverse said motors, a control valve operable in one position to afford a relatively free flow of fluid through said cam operating motor and operable to a second position to restrict the flow of fluid through said cam operating motor for varying the rate of movement of said tool toward the work, gauging means dependent upon the reduction of the work to a predetermined size for actuating said valve to its second position, and means dependent upon a further reduction of the work to a second predetermined size for actuating said motor reversing valve to move said tool away from the work, the inclination of said cam being such that any further reduction of the work by operation of said tool after initiation of the operation of said reversing valve will lie within a predetermined permissible working tolerance.

CHARLES J. ASTROWSKI.