Jan. 21, 1936. W. ARTER ET AL 2,028,642

GRINDING MACHINE

Original Filed Sept. 24, 1930 6 Sheets-Sheet 1

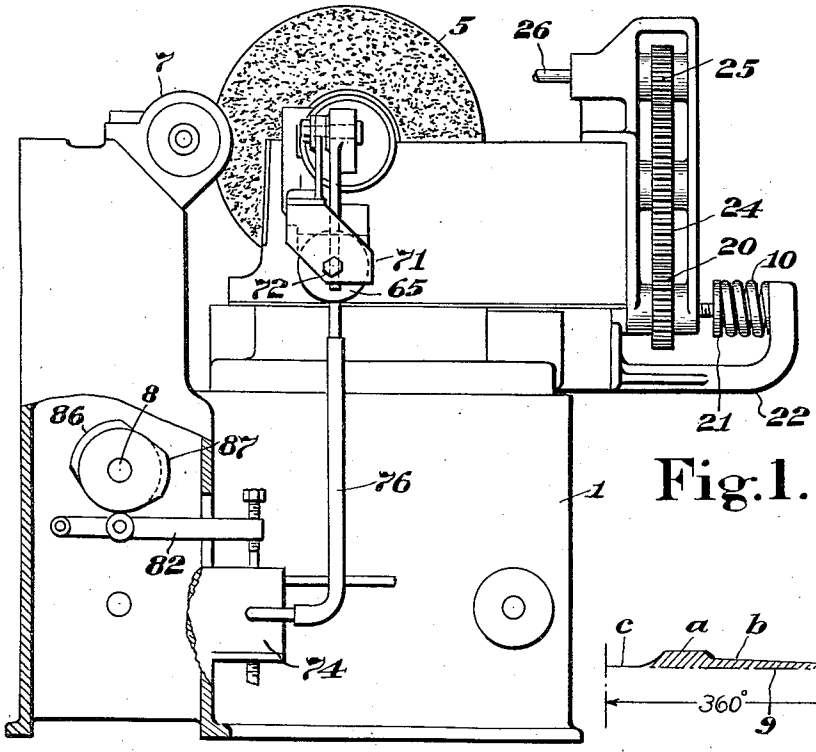


Fig.1.

Fig.3.

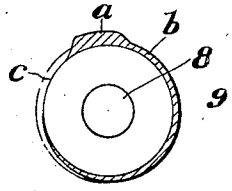


Fig.4.

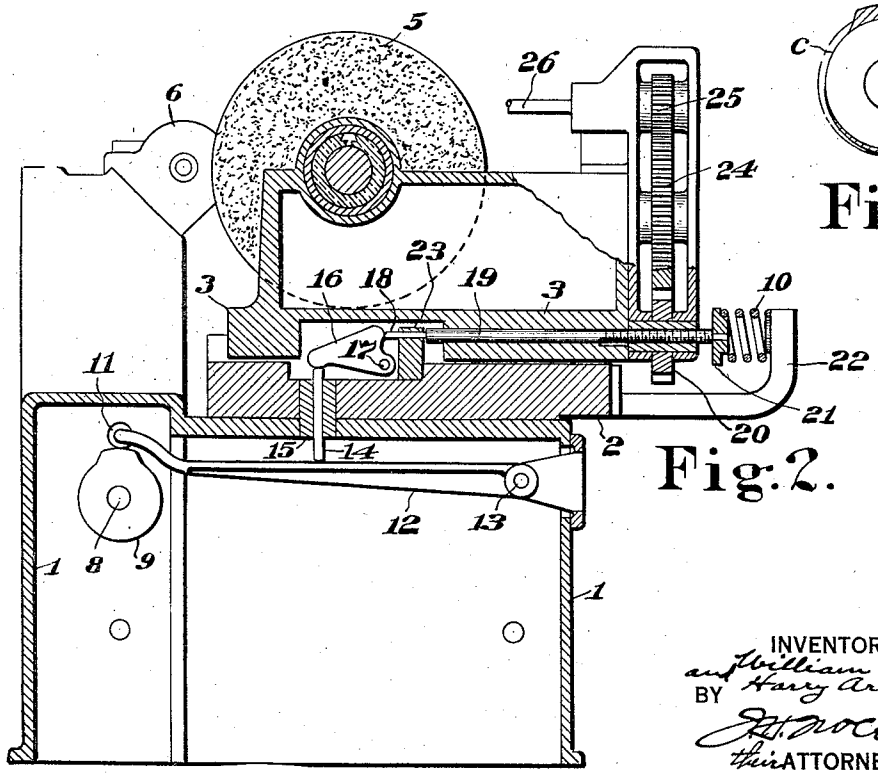


Fig.2.

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GRINDING MACHINE

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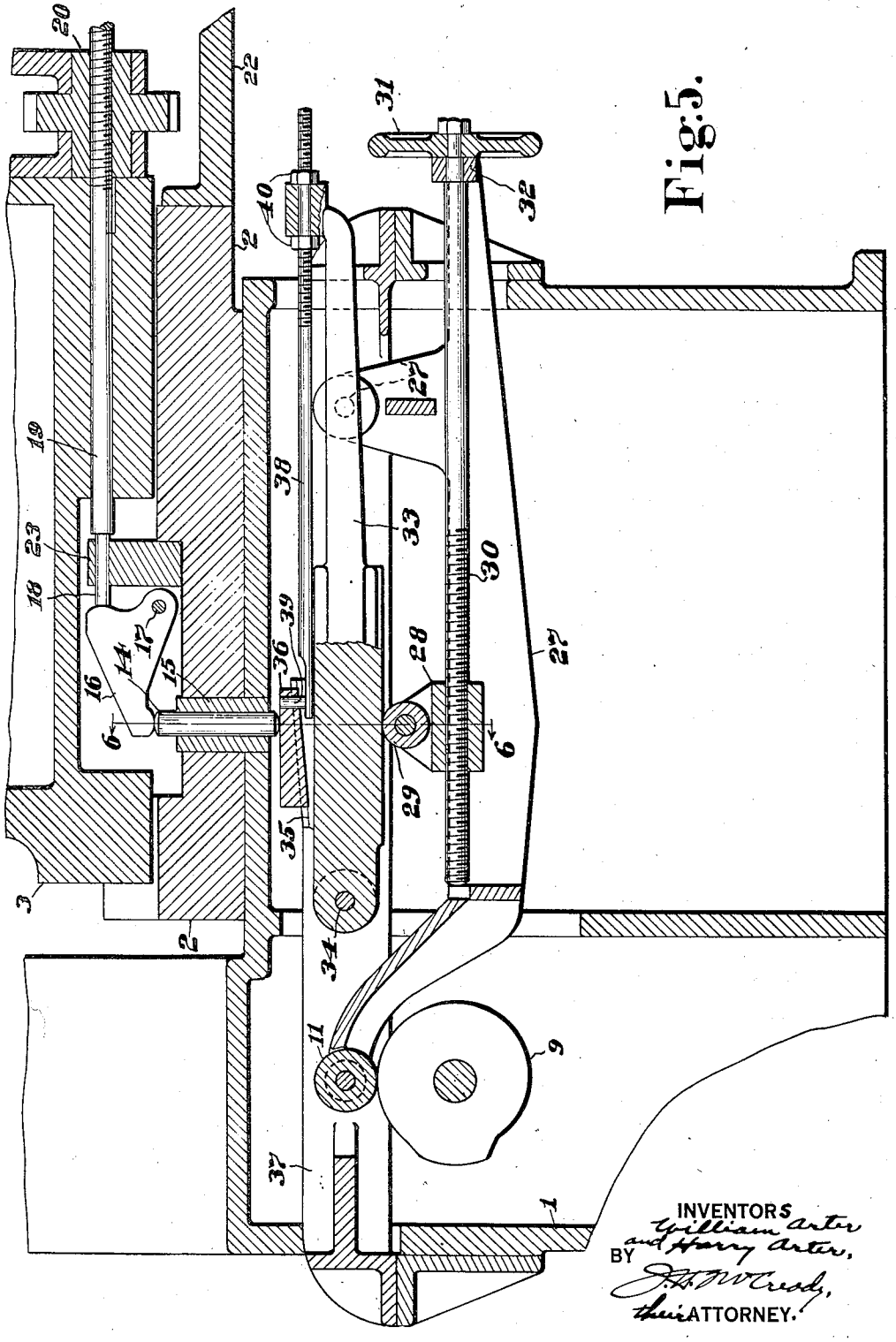


Fig.5.

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GRINDING MACHINE

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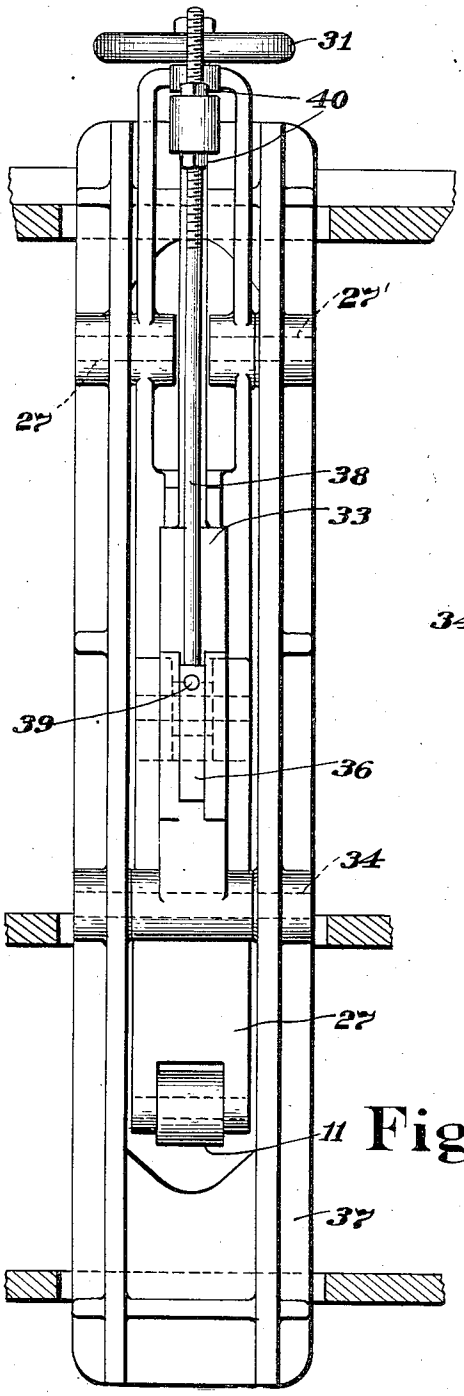
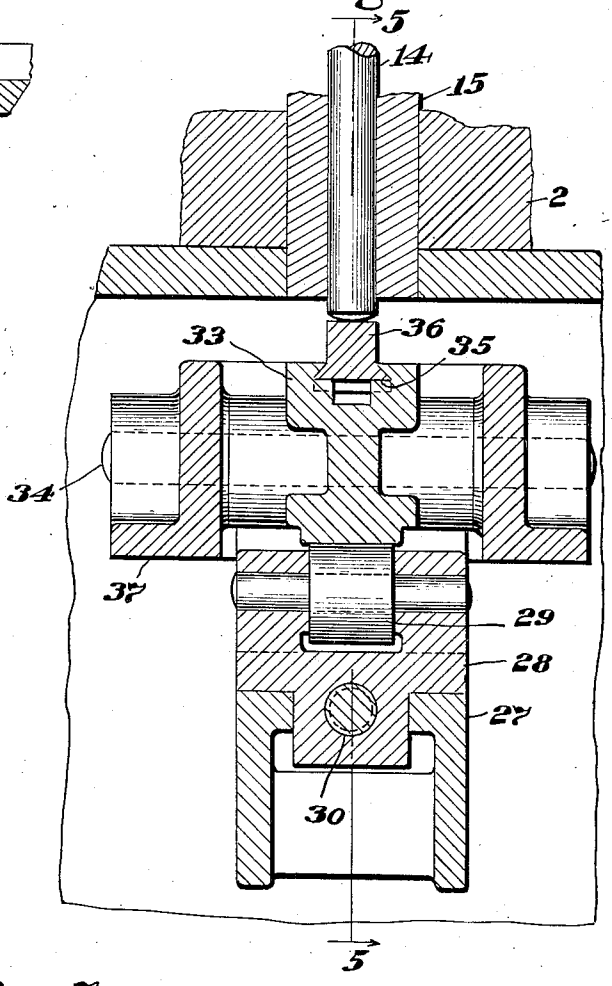


Fig. 7.

Fig. 6.



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GRINDING MACHINE

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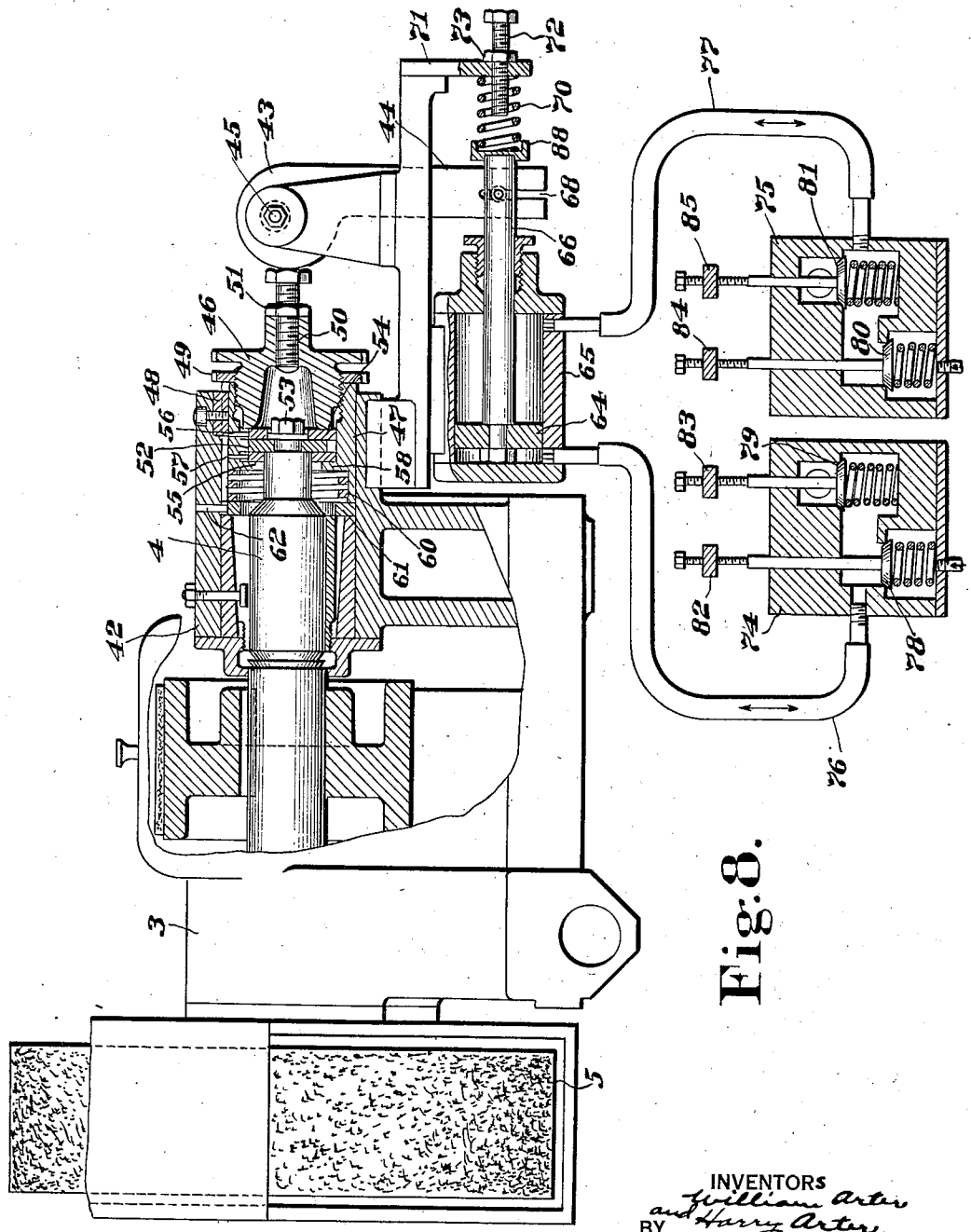


Fig. 8.

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GRINDING MACHINE

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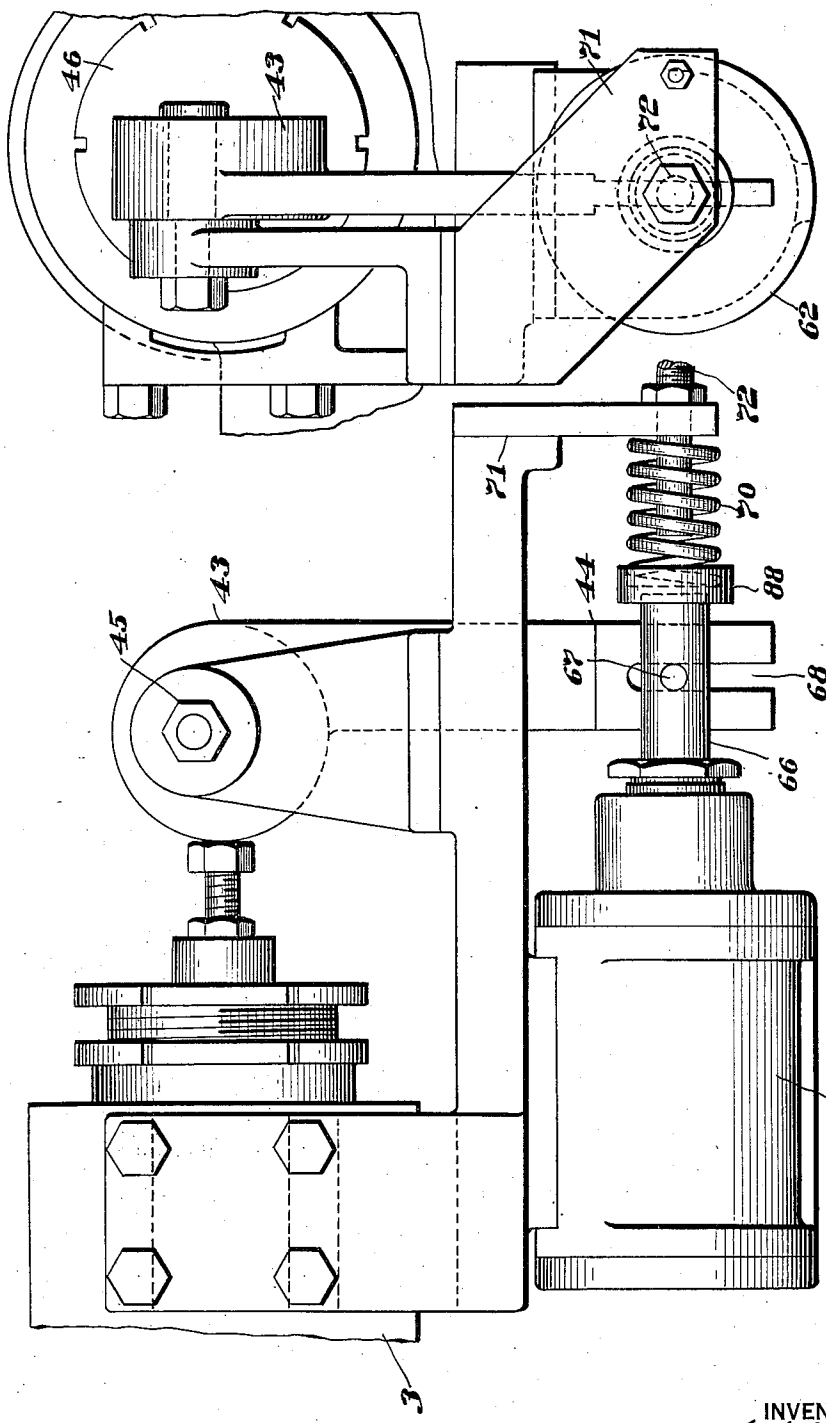


Fig.10.

Fig.9.

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GRINDING MACHINE

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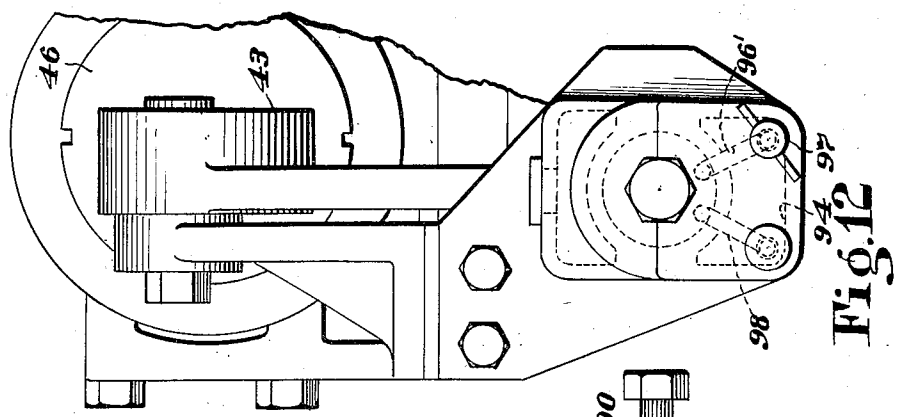


Fig. 12

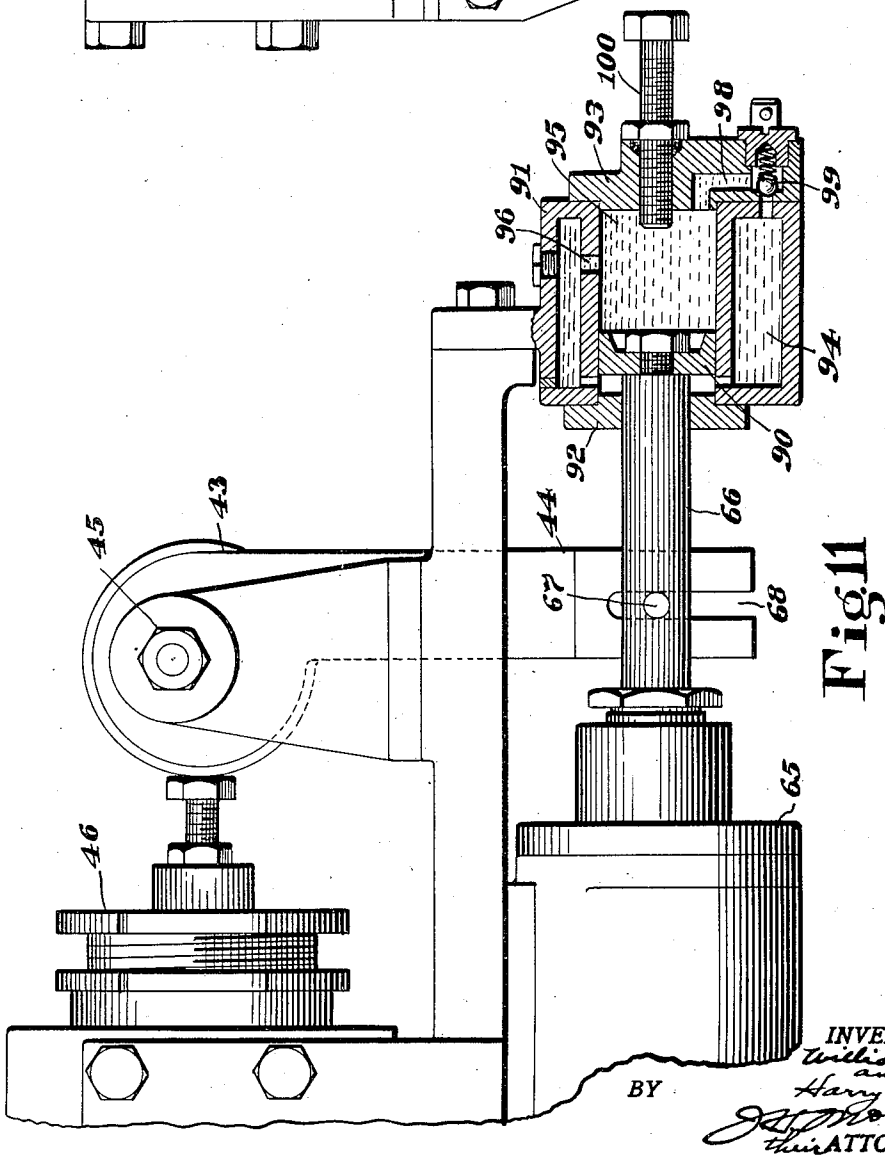


Fig. 11

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UNITED STATES PATENT OFFICE

2,028,642

GRINDING MACHINE

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Application September 24, 1930, Serial No. 484,070
Renewed January 13, 1934

16 Claims. (Cl. 51—50)

This invention relates to grinding machines of the automatic type.

In machines of this character mechanism is provided for producing automatically a relative approaching and receding movement of the grinding wheel and the work. Usually this is accomplished by a power driven cam operated through suitable connections with the grinding wheel support or the work support. In most machine organizations it is more convenient to move the grinding wheel, and in a typical construction provision is made for producing a relatively quick receding movement of the wheel and a slow approaching movement followed by a dwell during which the wheel "grinds out" the work or reduces it to the desired dimension. In handling some kinds of work it is desirable to make the rate of approach of the wheel considerably slower than in other cases. For some purposes, also, a shorter approaching movement and a longer dwell or grinding out period is desirable than in others. These requirements have necessitated the use of different cams in order properly to control the relative movements of the wheel and work.

The present invention deals with these requirements, and it aims to devise an organization in which a single cam can be used to satisfy a great variety of these conditions so that the necessity for changing cams and for using cams of different designs will be avoided, or at least greatly reduced.

In grinding some kinds of work, as for example shouldered pins or bushings, it is desirable not only to produce the relative approaching and receding movement of the work and wheel, as just described, but also to produce a relative traversing movement of these parts axially of the work and to control the traverse accurately, at least at that end of the movement at which the shoulder is ground. To provide a mechanism for performing this operation quickly, accurately and automatically constitutes a further object of the invention.

The nature of the invention will be readily understood from the following description when read in connection with the accompanying drawings, and the novel features will be particularly pointed out in the appended claims.

In the drawings,

Figure 1 is an end view, partly in section, of parts of an automatic grinding machine embodying features of this invention;

Figure 2 is a vertical sectional view through a portion of the machine shown in Fig. 1;

Figs. 3 and 4 are development and diagrammatic views, respectively, of one of the cams shown in Fig. 2;

Fig. 5 is a vertical sectional view substantially on the line 5—5, Fig. 6;

Fig. 6 is a vertical sectional view approximately on the line 6—6, Fig. 5;

Fig. 7 is a plan view, partly in section, showing more particularly the lever mechanism illustrated in Fig. 5;

Fig. 8 is a view, partly in side elevation and partly in vertical section, illustrating a mechanism embodying features of this invention for giving the grinding wheel an axial traversing movement;

Fig. 9 is a side elevation on a larger scale of certain of the parts shown in Fig. 8;

Fig. 10 is an end view of the mechanism shown in Fig. 9; and

Figs. 11 and 12 are sectional and end views, respectively, of a mechanism which may be substituted for certain of the parts shown in Figs. 8 and 9.

For convenience the invention has been shown in the drawings as applied to the grinding machine shown in United States Letters Patent No. 1,736,967, although it will be evident that the invention is equally useful in other grinding machines.

Referring first to Figs. 1 and 2 the machine there shown comprises a frame 1 on which is mounted a horizontal bed 2 arranged to be adjusted angularly about the pivot bushing 15. The bed is provided with guideways in which a support or head 3 is slidably mounted, said support carrying a wheel spindle 4 on which the grinding wheel 5 is secured. This machine is designed especially to grind pieces of work having cylindrical or tapered surfaces, and the work is supported in spindles mounted in a head stock 6 and tail stock 7, Figs. 2 and 1, respectively. All of these parts may be constructed, arranged and operated in the manner disclosed in said Patent No. 1,736,967, and reference should be made thereto for a more complete disclosure of the organization and operation of the machine.

The slidable mounting of the wheel support or wheel head 3 permits the wheel to be moved toward and from the work, and such movement of the wheel toward the work is produced by a spring 10, Figs. 1 and 2, under control of a cam. The relative receding movement of the work and wheel is produced by a power driven mechanism which includes a cam 9 mounted on the cam shaft 8 corresponding to the shaft 49 of the machine above referred to. A roll 11 runs on the

periphery of the cam 9 and is carried by a lever 12 which is fulcrumed on the machine frame at 13. Bearing on the upper side of this lever is a pin or plunger 14 extending through the bushing 15, previously referred to, and abutting at its upper end against one arm of a bell crank lever 16 which is fulcrumed on the bed 2 at 17. Another arm of this lever bears against a horizontal pin or plunger 18 which, in turn, abuts against the end of a horizontal rod 19 threaded through the hub of a gear 20 mounted to revolve in a casing which is secured rigidly to the wheel head 3 and to all intents and purposes forms a part of it. At its outer or right-hand end, Fig. 2, the rod 19 bears against a collar 21 which is backed up by the spring 10, the opposite end of the spring abutting against a bracket 22 rigid with the bed 2.

It will be clear from an inspection of Fig. 2 that as the cam 9 rotates and swings the lever 12 up and down on its fulcrum 13, the upward movement of this lever will be transmitted through the pin 14, bell crank lever 16, plunger 18 and rod 19 to the wheel head or wheel support 3, thus moving the grinding wheel 5 away from the work. As the lever 12 drops the spring 10 will force the grinding wheel in the opposite direction or toward the work, but this movement will be controlled by the cam 9 and also will be limited by the engagement of the left-hand end, Fig. 2, of the rod 19 with the stationary stop or part 23 through which the pin 18 slides, this stop 23 being rigidly secured to the bed 2.

The extent to which the grinding wheel 5 is caused to approach the axis on which the work revolves may be adjusted by revolving the gear 20 in the proper direction to move the wheel support 3 toward the right or left, Fig. 2. In order to facilitate this adjustment the gear 20 is connected through an intermediate gear 24 with another gear 25 fast on the shaft 26 which runs to the front of the machine, these gears 20, 24 and 25 corresponding to the gears 187, 188 and 190 of the machine shown in Patent No. 1,736,967, and the shaft 26 corresponding to the shaft 191 of said patent and being equipped with indicating mechanism similar to that shown in the patent.

Referring to Figs. 3 and 4 it will be seen that the cam 9 there shown includes a rise *a*, a relatively long incline *b*, and a dwell *c*. The rise produces a relatively abrupt movement of the wheel 5 away from the work and holds the wheel in a backward position for a relatively short period of time during which the finished piece of work is removed and another piece substituted for it. The incline *b* permits a gradual approaching movement of the wheel 5 toward the work, the wheel coming in contact with the work and commencing the grinding operation at some time during this approaching movement, and the dwell *c* preventing further approaching movement of the wheel while the "grinding out" operation takes place. Almost always the adjustment of the rod 19 is such that it strikes the stop 23 before the roll 11 engages the dwell portion *c* of the cam so that a longer period of dwell than that provided for by the design of the cam is obtained, since the engagement of the rod 19 with the stop 23 positively prevents the wheel 5 from moving further toward the work.

The foregoing mechanism per se is not of our invention. As above indicated, it frequently is necessary to change cams in order to control the movements of the grinding wheel in the manner desired to suit the requirements of individual jobs. In Figs. 5, 6 and 7 we have illustrated a mechanism which obviates this difficulty. This mechanism uses many of the parts of the construction shown in Figs. 1 and 2, and such parts are designated by the numerals used in the latter figures. It includes a lever 27 fulcrumed at 27' on a part 37 of the machine frame and carrying a roll 11 to run on the periphery of the cam 9. Adjustably mounted on the upper edge of the lever 27 is a slide 28 carrying a roll 29. A screw threaded shaft 30 extends through the slide 28 and engages corresponding threads thereon and is provided at its right-hand end, Fig. 5, with a hand wheel 31, this shaft being supported at the latter end in a bearing 32 which is formed in or supported by the lever 27. Resting on the roll 29 is a second lever 33, fulcrumed at 34 on the frame piece 37, and provided on its upper side with an inclined guideway 35, Figs. 5 and 6, in which a wedge 36 is mounted. The pin or plunger 14 rests on the upper horizontal surface of the wedge 36 so that the motion of the lever 27 produced by the cam 9 is transmitted through the slide 28, roll 29, lever 33, and wedge 36 to the pin 14.

In order to adjust the wedge in its inclined guideway, a horizontal rod 38 is connected to the wedge by a pin 39 and is extended slidably through a hole in the right-hand end, Fig. 5, of the lever 33. The right-hand end portion of the rod is screw threaded to receive nuts 40—40 by means of which the rod and the wedge may be adjusted longitudinally and locked in any position of adjustment.

It will be clear from an inspection of Fig. 5 that when the axis of the roll 29 is in alinement with that of the pin 14 this mechanism will control the movement of the wheel 5 in the manner above described in connection with the mechanism shown in Fig. 2. If, however, the slide 28 is adjusted to move the point of contact of the roll 29 with the lever 33 either toward the right or left, the movement transmitted from the cam 9 to the grinding wheel will be changed very materially. Such an adjustment changes the length of the arm of the lever 33 through which the cam 9 acts, and correspondingly changes the throw of this arm. The effect is to multiply the movement of the lever produced by the cam by a figure depending upon the degree of the adjustment, and the movement of the grinding wheel is correspondingly changed. It will be observed that the two fulcra 27' and 34 are located at opposite sides of the load point and that adjustment of the slide 28 may be such as to make the lever 33 operate either as a lever of the second or the third class, as desired.

Since the movement of the lever 33 is transmitted through the wedge 36, the plunger 14, and bell crank lever 16 to the wheel support or wheel head, an adjustment of the wedge 36 will result in moving the wheel head toward or from the work, and will correspondingly change the position of the outer limit of the movement transmitted to said head. Such an adjustment, however, still leaves the inner limit of movement of the wheel head subject to the control or adjustment afforded by the engagement of the rod 19 with the fixed stop 23.

It will be clear, therefore, that with this arrangement both the rate of relative approaching movement of the wheel and work and the ratio between the length of said approaching movement and the grinding out period can be ad-

justed at will. This is a very important practical advantage in using these machines in production.

The mechanism for producing the relative traversing movement of the grinding wheel and the work is illustrated in Figs. 8, 9 and 10. In this case, as in that of the relative approaching and receding movement of the tool and work, it is immaterial from the standpoint of the final result obtained whether the work is moved or the grinding wheel, or both. It is more convenient, however, to move the wheel than the work, and the mechanism shown, therefore, is designed in this manner, although it should be understood that an arrangement for moving the work is the equivalent of the construction for moving the wheel. Referring to Fig. 8 it will be seen that the wheel spindle 4 is mounted in the wheel head to reciprocate axially. The bearing bracket 42 which forms part of the wheel head 3 is provided with tapered bearings which may be adjusted to take up wear and which support one end of the spindle 4 accurately for rotation. Similar bearings, not shown, are provided for supporting the part of this spindle adjacent to the wheel 5.

The mechanism for reciprocating this spindle comprises a cam 43 formed on one end of a lever arm 44 and mounted in the machine frame to rock about a shaft or pivot 45. Means, which will later be described, is provided for rocking this cam in a predetermined time relationship to the other operations of the machine, and movement is transmitted from this cam to the spindle 4 through a cam follower of peculiar design. This follower includes a cap nut 46 threaded into a sleeve 47 which is mounted to slide in the bore of the bearing bracket 42. A key 48 fitting in a groove in the upper side of the slide prevents the follower from rotating. A lock nut 49 fastens the parts 46 and 47 securely together while permitting the former to be adjusted relatively to the latter. The follower also includes a bolt 50 threaded into the nut 46 with its head bearing against the periphery of the cam 43, a check nut 51 being provided to lock the bolt in an adjusted position.

In order to connect the follower with the spindle 4 without interfering with the rotary motion of the spindle, a washer 52 is secured to the end of the spindle by a bolt 53, and it is located between two thrust collars 54 and 55, respectively, which are carried by the follower 46—47, one of these thrust collars being held against rotation by a pin 56 and the other by a pin 57. It will be seen that the slide 47 has an inwardly extending flange 58 against which the thrust collar 55 bears, and that the other collar 54 abuts against the end of the nut 46 so that adjustment of the nut in the slide 47 determines the clearance between the washer 52 and the thrust collars 54 and 55. A strong coiled spring 60 is located in the rearward extension of the slide 47 and abuts at one end against the flange 58 of said slide and at its opposite end against a ring 61 which bears against one of the bearing bushings for the spindle 4, this ring being held against rotation by a pin 62. This spring, therefore, tends constantly to hold the bolt 50 of the cam follower against the periphery of the cam 43, but yields as the cam forces the follower inwardly. Since the spindle 4 and the cam follower are connected together for axial movement, the spindle and the grinding wheel 5 which it carries are compelled to move in unison with the cam follower.

While the cam 43 can be rocked in several ways, we prefer to use a fluid pressure mechanism for this purpose because it can be made to give a very steady movement, the range of which can be easiy adjusted, and particularly because it is easily and accurately controlled. This mechanism comprises a piston 64 working in a cylinder 65 and mounted on a piston rod 66, the rod being connected to the lower end of the cam lever 44 by a pin or roll 67 extending transversely through the rod and through a slot 68 in the lever. A coiled spring 70 abutting at one end against the piston rod and at its opposite end against a bracket 71 fixed to the frame, opposes the movement of the piston in one direction and therefore tends to make this movement steadier. The range of movement of the piston in the latter direction is limited by a screw or bolt 72 threaded through the bracket 71 and locked by a check nut 73.

Oil or other fluid under pressure is supplied from any convenient source and it is conducted to and from the cylinder 65 through valve casings 74 and 75 and pipes 76 and 77, respectively, which connect these valve casings with the cylinder. The flow of fluid to and from the cylinder is controlled by valves 78, 79, 80 and 81, respectively, Fig. 8, these valves having stems to cooperate with levers 82, 83, 84 and 85 for operating the respective valves. Preferably a screw is threaded through each lever and bears against the end of its respective valve stem, as shown in Figs. 1 and 8. These levers are arranged to be operated by cams such as those indicated at 86 and 87, Fig. 1, on the cam shaft 8, previously referred to, and in a manner which will be obvious from an inspection of Fig. 1.

With this arrangement the grinding wheel can be traversed relatively to the work, the period of traversing movement can be accurately timed, and the extent of said movement can be accurately adjusted. As the piston rod 66 moves toward the right and swings the cam 43 in a counterclockwise direction, the spring 60 slides the entire cam follower outwardly, or toward the right, carrying the spindle 4 and grinding wheel 5 with it. On the reverse movement of the piston rod 66 the cam 43 forces the cam follower inwardly. It should be noted that in grinding shouldered work, such as shouldered pins and bushings, the work is so placed in the machine that the wheel 5 is moved toward the shoulder while the piston rod 66 is moving toward the right, Fig. 8. The movement of the grinding wheel toward the shoulder is positively limited by the engagement of the end of the piston rod, or of the spring base 88 which it carries, with the end of the stop screw 72. Consequently, the grinding of the shoulder can be made very accurate. Adjustment of the grinding wheel axially with reference to the work is produced by adjusting the screw 50.

Where an exceptionally steady traversing movement is desired, the spring 70 may be replaced by the dash pot arrangement shown in Figs. 11 and 12. In this construction a small piston 90, Fig. 11, is secured to the outer end of the piston rod 66 and works in a cylinder block 91 provided with cylinder heads 92 and 93. The cylinder block 91 is secured rigidly to the machine frame and it is chambered to provide an oil reservoir 94. As the piston 90 moves toward the right, oil or other fluid is forced out of the cylinder 95 through an oil duct or port 96 into the oil reservoir 94. A relatively free flow of oil occurs at this time so that the dash pot offers no

substantial resistance to the approaching movement of the wheel head. As soon, however, as the piston 90 passes the port 96, the further outflow of oil from the cylinder takes place through the duct 96', Fig. 12, which is equipped with a needle valve 97. This valve may be so set as to make the rate of flow of the fluid very slow. Upon the return movement of the piston 90 oil flows relatively freely from the reservoir 94 into the cylinder 95 through a duct 98 equipped with a ball check valve 99 which permits the return flow only through this duct, until after the piston has passed the port 96, at which time a rapid return flow of the fluid can also occur through this port. A stop screw 100 is threaded through the cylinder head 93 in position to engage the end of the piston rod 66 within the cylinder 95 to positively stop the right-hand movement of the piston rod in exactly the same way that this movement is stopped by the screw 72 in the construction shown in Figs. 8, 9 and 10.

A traversing mechanism of this character is readily adjustable to satisfy a wide variety of conditions so that changes to accommodate different kinds of work usually can be made by adjustment without requiring any change or replacement of machine parts.

The mechanism shown in Figs. 5, 6 and 7 for controlling the relative approaching and receding movements of the grinding wheel and the work can be adjusted to accommodate the requirements of a wide variety of conditions. It will be observed that the cam 9 gives a certain time period within which the approaching movement and the "grinding out" operation must be performed. The entire period between the start of the wheel head toward the work and the beginning of its movement away from the work may be considered as divided into three periods or stages. First, an approaching movement which continues until the wheel comes in contact with the work, this part of the movement preferably being made relatively rapid; second, a continuation of said approaching movement during which the grinding wheel is acting on the work and performs the greater part of the operation of removing stock or metal from the work, this period terminating when the end of the rod 19 strikes the stop 23; and third, a "grinding out" period during which the axes of the work and the grinding wheel remain relatively stationary. This mechanism provides for the convenient adjustment of these three stages or periods, and this is important in changing from one kind of work to another. At the same time the rate of removal of the stock or metal from the work can be controlled as desired. The capacity for varying these time functions of the machine is a very important practical advantage.

Essentially the same control is afforded by the mechanism shown in Figs. 11 and 12 over the axial traverse of the grinding wheel to enable it to grind against the shoulder. It will be evident from an inspection of Figs. 8, 11 and 12 that the limit of the grinding stroke of the wheel toward a shoulder is determined by the adjustment of the screws 72 or 100. Also, that the needle valve 97 can be so set that the movement of the piston 90 toward the stop 100 after said piston has passed the port 96 will be slower than that permitted while the port 96 is open. The length of the "grinding out" period of the wheel against the shoulder on the work will be determined by the length of time which the piston 90 rests against the stop 100. It will be evident from the foregoing that by properly adjusting the screws 50 and 100, the point in the operation of the wheel on the work at which the speed of traverse changes may be adjusted, as desired. In other words, the operator may select both the length of the slow motion stroke and the time in the traverse at which the change in velocity will occur. This is a particularly desirable feature in a machine of this character.

While we have herein shown and described preferred embodiments of our invention, it will be understood that the invention is susceptible of embodiment in other forms without departing from the spirit or scope thereof.

Having thus described our invention, what we desire to claim as new is:

1. In an automatic grinding machine, the combination of a grinding wheel support; a work support; a machine bed having guideways upon which one of said supports is mounted for sliding movement to produce relative approaching and receding movements of the work and grinding wheel; a rod adjustable in said slidable support; screw threaded means for adjusting said rod relatively to said support; power driven mechanism operable through said rod to control said approaching movement; and a stop rigid with the machine frame for engaging said rod and limiting said approaching movement, said mechanism comprising a power driven cam, a lever operated thereby, means for transmitting the motion of said lever to said rod, said cam having a portion to control said relative approaching movement and another portion to permit the grinding out operation at the end of said approaching movement, and means adjustable to vary the ratio between said approaching and grinding out periods.

2. In an automatic grinding machine, the combination of a grinding wheel support; a work support; a machine bed having guideways upon which one of said supports is mounted for sliding movement to produce relative approaching and receding movements of the work and grinding wheel; and mechanism for controlling said approaching movement; said mechanism including a cam, a lever operated thereby, a second lever, connections between said levers for operating the second lever from the first lever, said connections being adjustable to vary the throw of said second lever imparted to it by said cam, and means for transmitting motion from said second lever to said slidable support.

3. In an automatic grinding machine, the combination of a grinding wheel support; a work support; a machine bed having guideways upon which one of said supports is mounted for sliding movement to produce relative approaching and receding movements of the work and grinding wheel; and mechanism for producing and controlling said movements; said mechanism including a power driven cam, a lever operated thereby, a second lever lying approximately parallel to the first lever and adjacent to it, a slidable connection between said levers adjustable to vary the length of the effective arm of the second lever, means for transmitting motion from said second lever to said slidable support, and means for moving said slidable support in a direction opposite to the movement thereof produced by said cam.

4. An automatic grinding machine according to preceding claim 3 characterized by the fact that the second lever carries a wedge adjustably mounted thereon through which the motion of

said second lever is transmitted to said slidable support.

5. In an automatic grinding machine, the combination of a grinding wheel support; a work support; a machine bed having guideways upon which one of said supports is mounted for sliding movement to produce relative approaching and receding movements of the work and grinding wheel; and mechanism for producing and controlling said movements; said mechanism including a power driven cam, a lever operated thereby, a second lever lying approximately parallel to the first lever and adjacent to it, connections for transmitting motion from said first lever to said second lever comprising a slide adjustable along the first lever to change the effective leverage ratio of said levers, screw threaded means for adjusting said slide, and means for transmitting motion from said second lever to said slidable support.

6. In an automatic grinding machine, the combination with a work support, a grinding wheel, a spindle supporting said wheel and bearings for said spindle, of mechanism for reciprocating said wheel and spindle comprising a rocking cam, a follower engaging said cam and connected with said spindle to cause said spindle and follower to move axially in unison, a spring for holding said follower against said cam, a piston connected with said cam to rock it, a cylinder in which said piston works, means for supplying fluid under pressure to said cylinder, said means including valves, and cam mechanism for operating said valves in a predetermined order.

7. A grinding machine according to preceding claim 6 having adjustable means for positively limiting the movement of said piston in one direction, and means for cushioning the movement of said piston in said direction.

8. In an automatic grinding machine, the combination with a work support, a grinding wheel, a spindle supporting said wheel and bearings for said spindle, of mechanism for reciprocating said wheel and spindle comprising a rocking cam, a follower engaging said cam and slidable in the bore of the wheel head and at the end of the wheel spindle, connections between said follower and said spindle for causing the spindle to reciprocate axially in unison with the follower, a spring in said bore for holding said follower against said cam, a power driven cam, and connections for causing the latter cam to operate said rocking cam.

9. In an automatic grinding machine, the combination with a work support, a grinding wheel, a spindle supporting said wheel and bearings for said spindle, of mechanism for reciprocating said wheel and spindle comprising a cam, a follower engaging said cam and connected with said spindle to cause said spindle and follower to move axially in unison, a spring for holding said follower against said cam, means for operating said cam, and a fluid pressure mechanism for resisting the movement of said wheel and spindle produced by said spring and constructed for adjustment to afford a materially greater resistance during one portion of such movement than at another portion thereof.

10. In an automatic grinding machine, the combination of a grinding wheel support; a work support; a machine bed having guideways upon which one of said supports is mounted for sliding movement to produce relative approaching and receding movements of the work and grinding wheel; a rod adjustable in said slidable support; means for adjusting said rod relatively to said support; and power driven mechanism operable through said rod to control said relative approaching movement; said mechanism including a cam, a lever operated thereby, means adjustable to multiply the movement of said lever produced by said cam, and means for transmitting motion from said lever to said rod.

11. In an automatic grinding machine, the combination of a grinding wheel support; a work support; a machine bed having guideways upon which one of said supports is mounted for sliding movement to produce relative approaching and receding movements of the work and grinding wheel; a rod adjustable in said slidable support; means for adjusting said rod relatively to said support; and power driven mechanism operable through said rod to control said relative approaching movement; said mechanism including a cam, a lever operated thereby, means adjustable to vary the length of the arm of said lever through which said cam acts, and means for transmitting motion from said lever to said rod.

12. In a grinding machine, the combination of a grinding wheel, a spindle on which said wheel is mounted, a wheel head in which said spindle is operatively supported for axial reciprocating movement, fluid pressure actuated mechanism for reciprocating said wheel and spindle axially relatively to said wheel head, and additional fluid pressure means for controlling the velocity of said axial reciprocation, said means being constructed and arranged to change said velocity automatically at substantially a predetermined point in the reciprocating movement of said wheel.

13. In a grinding machine, the combination of a grinding wheel, a spindle on which said wheel is mounted, a wheel head in which said spindle is operatively supported for axial reciprocating movement, fluid pressure actuated mechanism for reciprocating said wheel and spindle axially relatively to said wheel head, means for automatically changing the rate of the movement so imparted to said spindle at substantially a predetermined point in its stroke, means for adjusting the length of said stroke, and additional means for adjusting the point in said stroke at which said change in rate will occur.

14. In a grinding machine, the combination of a grinding wheel, a spindle on which said wheel is mounted, a wheel head in which said spindle is operatively supported for axial reciprocating movement, a piston, a cylinder in which said piston works, valve means for controlling the admission of fluid to said cylinder to operate said piston, connections for transmitting the motion of said piston to said spindle to move the spindle axially, said connections being adjustable to vary at will the relationship between said piston movement and the spindle movement produced by it, and additional means for automatically changing the rate of said piston movement at substantially a predetermined point in its stroke.

15. In a grinding machine, the combination of a grinding wheel, a spindle on which said wheel is mounted, a wheel head in which said spindle is operatively supported for axial reciprocating movement, a piston, a cylinder in which said piston works, valve means for controlling the admission of fluid to said cylinder to operate said piston, connections for transmitting the motion of said piston to said spindle to move the spindle

axially, additional means for automatically changing the rate of said piston movement at substantially a predetermined point in its stroke, means adjustable to change the point in said stroke at which said change in rate will take place, and means for adjusting the length of the movement imparted to said spindle by said piston.

16. In a grinding machine, the combination of a grinding wheel, a spindle on which said wheel is mounted, a wheel head in which said spindle is operatively supported, means for supporting an article of work for the operation thereon of said grinding wheel, power operated mechanism for producing relative approaching and receding movements of said wheel and work fluid pressure actuated mechanism for relatively reciprocating said work and wheel in a definite time relationship to said approaching and receding movements of the work and wheel to produce a relative traverse of the wheel on the work in a direction transverse to said relative approaching and receding movement, means for automatically changing the rate of said relative traverse movement at substantially a predetermined point, and the means for adjusting said point.

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