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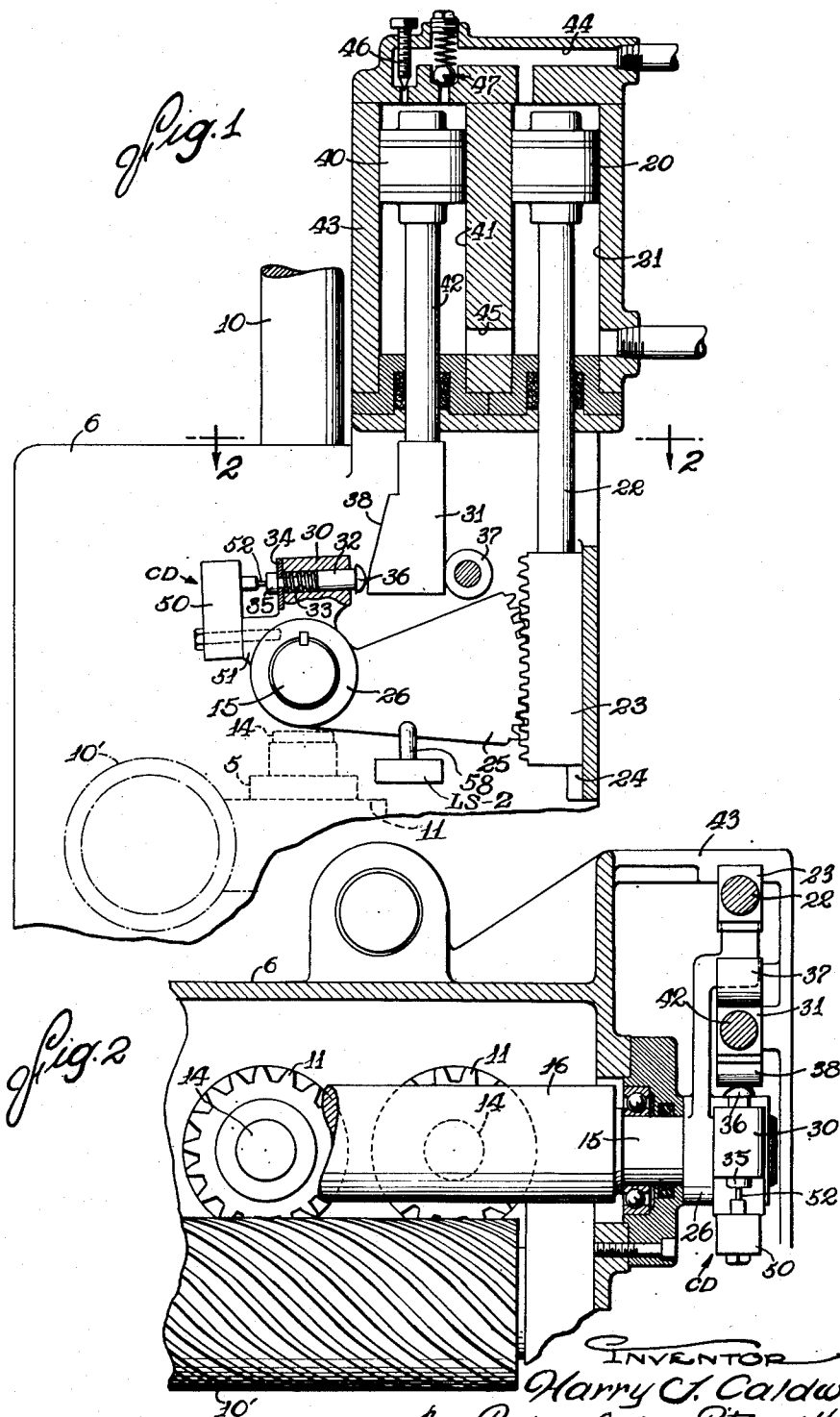
H. J. CALDWELL

2,345,581

MACHINE TOOL

Filed April 3, 1941

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

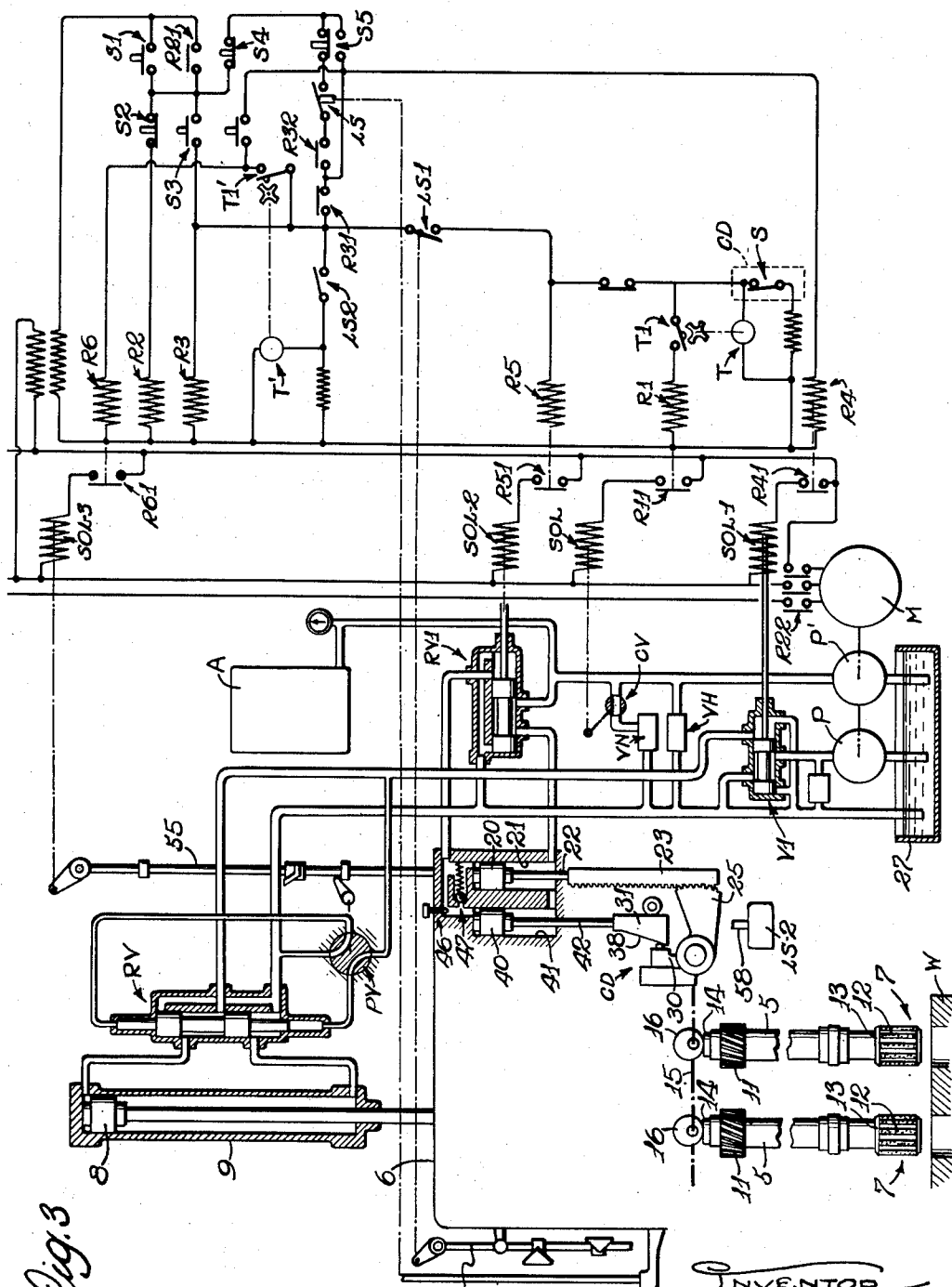


Fig. 3

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MACHINE TOOL

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17 Claims. (Cl. 51—34)

The invention relates to improvements in machine tools of the type in which the cutting action of a tool is regulated by the pressure with which it is applied to the work.

The general object of the invention is to provide improved controls for machine tools of the above general character operable automatically for adjusting the pressure of the tool to insure substantially uniform feeding of the same into the work.

The improved controls are particularly suitable for use in honing machines which utilize expandable and contractible abrasive tools. In the operation the tool is expanded to feed the abrasive elements thereof into operative engagement with the surface to be operated on. Occasionally, the abrasive elements of a tool become glazed or loaded with particles of material removed from the work thus preventing the elements from performing their metal removing function with normal efficiency. Under these circumstances, continued operation of the machine may result in scoring or otherwise damaging the work. Accordingly, another object of the invention is to provide improved means for continuously checking the cutting efficiency of the honing tool and for increasing the pressure on the abrasive elements in a manner such as to break down the glazed surface and restore the cutting efficiency of the elements when required.

A further object is to provide novel means for expanding a honing tool at a substantially uniform rate.

Still another object of the invention is to provide control means for automatically regulating the expansion of a honing tool to insure the finishing of the work exactly to the desired dimensions in a definite working cycle.

It is also an object of the invention to provide a novel method of detecting variations in the cutting efficiency of a tool of the pressure feed type.

Other objects and advantages of the invention will become apparent from the following detailed description of the preferred embodiment illustrated in the accompanying drawings in which:

Figure 1 is a side view, partly in section, of a hone expanding mechanism embodying the features of the invention, the mechanism being shown as incorporated in a conventional honing machine.

Fig. 2 is a horizontal sectional view of the mechanism taken substantially along the line 2—2 of Fig. 1.

Fig. 3 is a diagrammatic view showing the electrical and hydraulic operating and control circuits

and their relationship to the mechanical structure of the machine.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawings and will herein describe in detail a preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

By way of illustration, the invention has been shown in connection with a honing machine of the type having a plurality of vertically disposed tubular tool spindles 5 journaled on a head 6. At its lower end, each spindle carries a honing tool 7 (Fig. 3) adapted to be traversed axially of a cylindrical bore in a work piece W by reciprocation of the head. Reciprocation of the head is preferably effected by pressure fluid operated means including a piston 8 working in a cylinder 9 to which pressure fluid is supplied from a pump P under control of a reversing valve RV of well known construction. Simultaneously with their reciprocation, the honing tools are rotatably driven by a motor (not shown) through the medium of a drive shaft 10 and an elongated spiral gear 10' journaled in the head 6. The gear 10' meshes with pinions 11 keyed to the respective spindles.

The honing tool 7 is of the conventional type and, as shown in Fig. 3, comprises a series of elongated abrasive elements 12 arranged in circumferentially spaced relation upon a cylindrical carrier 13. The elements are yieldably held in a retracted position in well known manner to permit insertion of the tool into the work. During the honing operation the elements are fed radially outwardly into contact with the surface of the work by means of a push rod 14 extending axially through the spindle 5. In the exemplary machine the push rods for all the spindles are shifted simultaneously by a common actuator in the form of a rock shaft 15 journaled on the head 6. The rock shaft is formed with an eccentric cam portion 16 operative to depress the push rods and expand the honing tools when the shaft is rocked out of its normal rest position in a clockwise direction as viewed in Figs. 1 and 3.

While any suitable means may be utilized to rock the shaft 15 for the purpose above stated, it is preferred to utilize pressure fluid operated

means which permits accurate regulation of the pressure with which the abrasive elements of the tool are applied to the work. This means as herein shown comprises a double acting piston 20 working in a cylinder 21 mounted at one end of the head 6. The piston is connected by a rod 22 with a rack 23 slidably supported on a guideway 24 for movement transversely of the shaft 15. Movements of the rack are transmitted to the rock shaft through a segmental gear 25 having a hub 26 keyed to the shaft as shown in Fig. 1. Thus, when the piston is moved downwardly by introduction of pressure fluid into the upper end of the cylinder 21, the push rods are forced downwardly and act in well known manner to shift the abrasive elements of the hones outwardly against the surface of the work. Upon introduction of pressure fluid into a lower end of the cylinder 21, the piston is shifted upwardly to the position shown in Fig. 1 thus permitting the hones to contract in the usual way.

In the particular machine illustrated, pressure fluid is supplied to the hone expanding cylinder by a pump P' (Fig. 3) driven in tandem with the pump P by an electric motor M. To insure rapid initial expansion of the hones at the beginning of each working cycle, an accumulator A is provided for storing fluid under pressure between cycles. A reversing valve RV1 is arranged to direct the pressure fluid into either end of the cylinder 21 selectively and to connect the non-working end of the cylinder to a drain which returns the spent pressure fluid to a reservoir 27 for recirculation by the pumps P and P'.

In the normal operation of the machine, the pressure fluid supplied to the hone expanding cylinder is controlled by conventional relief valve VN connected to the discharge line of the pump P'. This relief valve is set to maintain the pressure at a value which enables the hones to operate in the most efficient manner and to remove a definite amount of metal from the surface of the work in a working cycle of predetermined length. At times, the abrasive elements of one or more of the hones may become glazed or loaded with particles of material removed from the work thereby materially reducing the cutting action of the hone so affected. It has been found, however, that the glazed surface of the abrasive elements can be broken down and the elements restored to normal operating efficiency by increasing the expanding pressure substantially above the normal operating pressure. To provide for such increase in pressure, a cut-off valve CV is arranged when closed to shut off the flow of pressure fluid from the pressure line to the relief valve. An auxiliary relief valve VH set to release at a pressure substantially above the releasing point of the valve VN is arranged to prevent the building up of excessive pressure in the hydraulic circuit.

The cut-off valve CV may, of course, be operated manually by the machine attendant when required. However, when manual operation is relied upon, close supervision of the machine operation is necessary to detect a glazed condition of the hone and make the necessary adjustments in time to prevent damage to the hone or work. This obviously increases production costs and is further objectionable because of the danger of interrupting production schedules.

The present invention overcomes the above difficulty by providing novel automatic means for quickly detecting any substantial reduction in

the cutting efficiency of the hone and for actuating the valve CV to effect a temporary increase in the hone expanding pressure such as to restore the hone to normal operation condition.

The detecting means in its preferred form comprises a pair of coacting members, one arranged to move at a rate proportioned to the actual rate of hone expansion and the other arranged to recede from the first member at a rate similarly proportioned to the desired rate of hone expansion. Thus, a predetermined constant relationship is maintained between these members as long as the hone continues to expand at its normal rate. When hone expansion lags, due to a reduction in the rate of metal removal, the relationship of the members is changed by the differences in their rates of movement. This relationship is utilized to control hone expanding pressure through the medium of a suitable control device CD.

In the preferred form of detecting means shown in Fig. 1 of the drawings, the member which moves in accordance with the actual rate of hone expansion comprises a radial arm 30 rigid with the gear hub 26 and projecting substantially at right angles to the segment gear 25. The other member which moves in accordance with the desired rate of hone expansion comprises an elongated metal block 31. The first mentioned member or arm is formed with a socket for slidably receiving a plunger 32 arranged to project beyond the front face of the arm. A coiled compression spring 33 interposed between a shoulder on the plunger and a retaining plate 34 fixed to the arm urges the plunger forwardly toward the projected position in which it is shown in the drawings. A headed bolt 35 attached to the inner end of the plunger coacts with the retaining plate to limit the forward movement of the plunger. Movement of the plunger in the opposite direction is limited by a flange 36 or similar lateral projection adjacent the outer end of the plunger. Movements of the plunger between the above limit positions serve to actuate the control device CD as will appear presently.

As herein shown, the member or block 31 of the detecting means is guided by a roller 37 for endwise movement transversely of the path described by the plunger in the rocking of the hone expanding shaft. One side of the block is cut away to define a plunger engaging surface 38 which is inclined with respect to the path of the block so as to gradually recede from the plunger tip as the block is moved downwardly from the normal rest position in which it is shown in Fig. 1.

At the beginning of an operating cycle, the parts occupy the positions shown in Fig. 1. The control member 31 thus presents the highest point on its inclined surface 38 in the path of the plunger 32. Upon initial introduction of pressure fluid into the hone expanding cylinder 21, piston 20 shifts the rack 23 downwardly and rocks the segment gear and its arm 30 in a clockwise direction. The plunger 32 moves forwardly with the arm until its tip engages the surface 38 and thereafter continued movement of the arm compresses the spring 33 and effects a relative shifting of the control device toward the plunger. The limit of such relative movement is determined by the engagement of the arm with the flange 36 of the plunger, the parts being so proportioned and adjusted that this engagement takes place substantially at the instant the abrasive elements of the hone operatively contact the surface of the work. This relative movement of

the control device and plunger, causes the device to be set for supplying pressure to the hone expanding cylinder at the normal operating pressure. In the particular embodiment illustrated, this setting of the control device results in the opening of the pressure control valve CV.

Simultaneously with the advance of the piston 20 and rack 23 to expand the hone, the control member 31 is started on its downward movement whereby the surface 38 of the member is caused to recede from the plunger at the same rate that the arm 30 will advance with normal hone expansion. Accordingly, as long as the normal hone expansion continues, the arm 30 and member 31 will maintain the same relative spacing and the plunger will be held in its operated or fully depressed position. Accordingly, the operation will continue with the hone expanded at normal pressure.

Interruption of hone expansion or any substantial reduction in the rate of expansion will be reflected by a corresponding retardation in the advance of the arm 30. Since the control member 31 continues its advance at a uniform rate, the surface 38 will tend to recede from the arm and allow the plunger 32 to move forwardly under the action of the compressed spring 33. Such movement of the plunger actuates the control device CD to its alternate position for momentarily closing the control valve CV whereby the pressure of the fluid supplied to the hone expanding cylinder is substantially increased. This momentary increase in pressure will usually restore the abrasive elements of the hone to normal operating efficiency so that the operation may proceed at the normal rate. Moreover, due to the increased pressure, the hone will tend to expand at an increased rate until the normal spacing of the arm 30 and control member 31 is restored. When this condition is attained, operation at normal hone expanding pressure is resumed.

While any suitable means may be utilized for moving the member 31, it is preferred to utilize pressure fluid actuated means such as a piston 40 working in a cylinder 41, the piston being connected with the member by a piston rod 42. As herein shown, the cylinder 41 and the hone expanding cylinder 21 are formed in a common cylinder block 43 provided with ducts 44 and 45 connecting the corresponding ends of the cylinders. The cylinders can thus be supplied with pressure fluid from a common source and synchronism of operation is thus insured.

The duct 44 is arranged to communicate with the upper end of the cylinder 41 through separate inlet and outlet passages. A needle valve 46 controls the flow through the inlet passage and provides convenient means for accurately regulating the rate of movement of the member 31. The outlet passage is provided with a check valve 47 herein shown as a valve of the spring pressed ball type arranged to permit rapid exhaustion of spent pressure fluid from the upper end of the cylinder so that the member 31 may be returned to normal rest position without delay at the end of the working cycle.

The control device CD may be of any suitable character. The exemplary control device comprises a single pole normally closed switch S (Fig. 5) preferably of the so-called microswitch type. This switch is enclosed in a housing 50 (Fig. 1) bolted or otherwise rigidly secured to a boss 51 formed on the hub 26 at one side of the arm 32. The switch has its actuator 52 positioned for en-

gagement by the head of the plunger carried bolt 35 whereby the switch contacts are opened when the plunger 32 is shifted to its operated position and closed when the plunger is returned to its projected position.

As shown in Fig. 3 the switch S is arranged to control the position of the pressure regulating or cut-off valve CV through a circuit organization including a conventional electrically operated timer T. Closure of the switch starts the timer which periodically closes a switch T1 in circuit with a relay R1. This relay upon becoming energized, closes a switch R11 to complete an energizing circuit for a solenoid SOL which then closes the valve CV. When the switch T1 is opened the relay R1 and solenoid SOL become deenergized and valve CV returns to its open position.

In practice, the timer T is adjusted so that the switch T1 is closed and the increased pressure is maintained on the hone long enough to insure breaking down of the glazed surface of the abrasive elements but not long enough to damage the elements. The timer, of course, continues in operation and periodically increases the pressure on the hone as long as the switch S remains closed, that is, until the lag in hone expansion is corrected.

A machine equipped with the novel apparatus above described may be operated with a minimum of supervision. Thus after the work has been properly set up for the reception of the tools, a switch S1 is momentarily actuated to energize a motor control relay R2. This relay completes a holding circuit for itself through a normally closed stop switch S2 by closing switch R21 and starts the various driving motors by closing suitable switches such as the switch R22 for the pump driving motor M. The normal and high pressure relief valves VN and VH are properly set, of course, and the needle valve 46 is adjusted for the desired working cycle.

The working cycle of the machine is initiated by momentary actuation of a cycle starting switch S3 and can be interrupted at any time by momentary actuation of a stop switch S4. Switch S3 when actuated completes a circuit for a cycle control relay R3 which, in turn, closes a switch R31 to complete a circuit for a control relay R4. The latter relay by closing switch R41 energizes solenoid SOL1 which opens a valve V1 to direct pressure fluid to the reversing valve RV. When the head 6 is in its upper or withdrawn position, the reversing valve is set in the position shown in Fig. 3 and thus effective to direct the pressure fluid into the upper end of the cylinder 9. The head is accordingly moved downwardly to insert the tools in the work. Thereafter the head is reciprocated through a plurality of working strokes under the control of a pilot valve PV actuated by the head through a control rod 55 in well known manner.

In its initial movement from retracted position, the head 6 closes a limit switch LS to complete a holding circuit for the cycle control relay R3 by way of the switch R31, a second switch R32 closed by the relay, and a normally closed manually operable "inching" switch S5. Relay R3 is thus enabled to maintain the machine in operation independently of the cycle starting switch S3. Upon sufficient advance of the head to insert the tools within the work, a second control rod 56 is actuated in well known manner to close a limit switch LS1 and thereby complete an energizing circuit for a control relay R5. The re-

lay closes its switch R51 to energize a solenoid SOL2 which acts to set the expansion controlling valve RV1 in hone expanding position. Pressure fluid is accordingly supplied to the upper ends of the hone expanding cylinder 21 and the companion timing cylinder 41 and the pistons working in these cylinders perform their respective functions in the manner previously described. If hone expansion proceeds at the normal rate, the switch S of the control device CD remains open and the hone is expanded with normal pressure as determined by setting of the relief valve VN. When hone expansion lags, switch S is closed and relay R1 is energized intermittently under control of the timer T to correspondingly increase the pressure on the hone by periodically closing the cut-off valve CV.

The working cycle is automatically terminated at the end of a predetermined interval measured by the rate of movement of the member 31. To this end, the member on approaching its lower limit position engages an actuator 58 (Figs. 1 and 3) to close a limit switch LS2. Closure of this limit switch starts a timer T' which, after an interval, closes its switch T1' to energize a pullout relay R6. This relay closes switch R61 to complete an energizing circuit for a pullout solenoid SOL3 which operates in well known manner to rock the control rod 55 into a position effective to permit the head 6 to return to fully retracted position. As the head reaches this retracted position, limit switch LS is opened to release the cycle control relay R3 and thus effectually terminate the working cycle of the machine.

It will be apparent from the foregoing that the invention provides control means of novel and advantageous character for automatically regulating the pressure with which a tool is applied to the work to insure substantially uniform feeding of the same into the work. The improved controls are particularly suitable for honing machines and include novel means for automatically detecting any substantial reduction in the operating efficiency of the hone as when the abrasive elements become glazed or loaded with particles of material removed from the work. Upon detection of this condition the machine is automatically adjusted to increase the pressure on the hone sufficiently to break down the glazed surface of the abrasive elements, such pressure being maintained only long enough to effect the desired result without damage to the elements.

I claim as my invention:

1. In a honing machine, in combination, a support for a plurality of expansible honing tools, a support for work to be operated on by the tool, means for relatively rotating and simultaneously relatively reciprocating said supports, a shaft journaled on the tool support operative when rocked from usual rest position to expand the tools, power actuated means for rocking said shaft, an arm rigid with the shaft, a plunger carried by said arm and movable therewith, means yieldably urging said plunger to a projected position, a shiftable block having an inclined edge portion disposed in the path of said plunger, said plunger being forced against the edge portion of the member and thereby shifted from said projected position to an alternate position when the shaft is rocked initially to expand the tools into engagement with the work, power actuated means for shifting said block to cause the edge portion to recede from the arm at a rate such that the plunger is held in operated position only while expansion of the tools proceeds

at a normal rate, and a control device arranged to be selectively set in accordance with the position of said plunger, said device being arranged to variably control said power actuated means.

2. In a honing machine, in combination, means for supporting an expansible abrasive tool, means for supporting work to be operated on by the tool, power actuated means for relatively rotating and simultaneously relatively reciprocating the tool and work through a definite working cycle, power actuated means for expanding the tool against the work with a substantially constant pressure normally effective to insure removal of all surplus stock from the work in the working cycle, control means rendered operative upon failure of the tool to remove stock from the work at substantially the normal rate, said detecting control means including a pair of cooperating members one movable at a rate proportioned to the actual rate of expansion of the tool and the other at a rate similarly proportioned to the normal rate of expansion of the tool, a part carried by said one member and arranged to engage the other member, said part being held in an operated position only while the members continue to move at substantially the same rate, means actuated according to the position of said part for regulating the pressure exerted by the tool on the work, and means actuated by the other of said members for terminating the working cycle of the machine.

3. The combination in a machine tool having pressure fluid operated means for feeding a metal removing tool to the work, of a pair of independently movable members, a plunger slidably supported on one of the members, means yieldably urging said plunger toward the other of the members, means for advancing said one member at a rate proportioned to the actual feed rate of the tool, said plunger being forced against the other member and thereby shifted to an operated position, means for moving the other member to cause it to recede from said one member at a rate similarly proportioned to the desired feed rate of the tool, said plunger being held in the operated position while said members advance at the same rate and returning to its alternate position when said one member lags, and a valve selectively actuated in accordance with the position of said plunger for controlling the pressure fluid operated means to effect a substantially uniform feed of the tool.

4. The combination in a machine tool having pressure fluid operated means for feeding a metal removing tool to the work, of a pair of independently movable members, a plunger slidably supported on one of the members, means yieldably urging said plunger toward the other of the members, means for advancing said one member at a rate proportioned to the actual feed rate of the tool, said plunger being forced against the other member and thereby shifted to an operated position, means for moving the other member to cause it to recede from said one member at a rate similarly proportioned to the desired feed rate of the tool, said plunger being held in the operated position while said members advance at the same rate and returning to its alternate position when said one member lags, an electrical switch adapted to be opened by movement of said plunger to operated position and closed by the return of the plunger to the alternate position, a timing device arranged to be started and stopped by the closing and open-

ing of said switch, and a valve operable periodically under control of said timing device for varying the pressure of the fluid supplied to the tool feeding means to maintain a substantially uniform rate of feed.

5. In a honing machine, in combination, means for supporting an expansible abrasive tool, means for supporting work to be operated on by the tool, power actuated means for relatively rotating and simultaneously relatively reciprocating the tool and work through a definite working cycle, power actuated means for expanding the tool against the work with a substantially constant pressure normally effective to insure removal of all surplus stock from the work in the working cycle, a control device adapted to operate when tool expansion falls below a predetermined rate, and means controlled by said device for temporarily increasing the pressure of the tool against the work.

6. The combination with means for relatively rotating and simultaneously relatively reciprocating a power expanded honing tool and a work piece, of control means adapted to respond to a reduction in the cutting efficiency of the tool comprising a member movable at a rate accurately proportioned to the actual rate of expansion of the tool, a second member having a surface portion adapted to be contacted by an element carried by the first member upon initial expansion of the tool, and means for moving said second member to cause said surface portion of the second member to recede from the first member at a rate similarly proportioned to the normal rate of expansion of the tool, said element advancing with the first member while the hone expansion proceeds at the normal rate and advancing relative to the first member to maintain contact with the second member when hone expansion is retarded, and a control device arranged for actuation by said element.

7. The combination in a honing machine having means for relatively rotating and simultaneously relatively reciprocating an expansible honing tool and the work to be operated on by the tool, of a movable actuator for expanding the tool, a member carried by said actuator for movement therewith, a second member disposed in the path of said first member, said members being relatively adjusted to a predetermined relationship upon initial expansion of the tool, means for withdrawing said second member from said first member at a substantially constant rate whereby said predetermined relationship is maintained only while the rates of movement of the members remain substantially the same and changing when the first member lags, a control device operable selectively in accordance with the relationship of said members, and means controlled by said device for regulating the pressure with which the hone is expanded.

8. The combination in a honing machine having means for relatively rotating and simultaneously relatively reciprocating an expansible honing tool and the work to be operated on by the tool, of a movable actuator for expanding the tool, a member carried by said actuator and movable therewith, a shiftable block having one edge portion disposed in the path of said member, means for shifting said block to cause the edge portion to recede from the member, a yieldable element carried by said member engageable with the edge portion of said block upon initial expansion of the tool, said element being shifted to an operated position upon such engagement and remaining in

operated position only as long as tool expansion continues at a normal rate, and a control switch actuated by said element.

9. A control device for machine tools having power actuated means for feeding a metal removing tool to a work piece, said control device comprising a first member movable at a rate proportional to the actual feed of the tool, a second member having a surface portion disposed in the path of said first member, means for shifting said second member to cause the surface portion to recede from the first member at a rate proportional to the desired feed of the tool, said members maintaining a predetermined relationship only while the actual feed rate of the tool substantially equals the desired feed rate, and means operative upon a change in said relationship in response to a lag in the actual feed rate for regulating the power actuated feed means.

10. The combination with means for applying a metal removing tool against a work piece with a pressure normally effective to produce a predetermined rate of feed, a member movable at a rate proportioned to the actual rate of feed of the tool, a second member disposed in the path of movement of said first member, means for causing said second member to recede from the first member at a rate proportioned to the predetermined feed rate, said members thereby remaining in definite spaced relation as long as the feed of the tool is maintained at said predetermined rate but separating when the feed of the tool lags, and means operative upon the separation of said members for increasing the pressure with which the tool is applied to the work.

11. The combination in a honing machine having a support for an expansible and contractible honing tool and a support for work to be operated on by the tool, means for relatively rotating and simultaneously relatively reciprocating said supports to repeatedly traverse the tool over the surface of the work, means for expanding the tool to cause it to remove surplus stock from the work surface at a predetermined rate, control means operative to automatically check the rate of stock removal, and means controlled by said control means in response to a decrease in the rate of stock removal below said predetermined rate for regulating said expanding means to momentarily increase the stock removing action of the tool above said predetermined rate.

12. The combination in a honing machine having an expansible and contractible hone, power actuated means for expanding the hone to exert a predetermined pressure on the work, means for relatively rotating and simultaneously relatively reciprocating the hone and the work to cause the hone to progressively cut away the surplus stock on the surface of the work and expand at a predetermined rate, said hone expanding at a corresponding predetermined rate during such cutting action, control means adapted to respond to a reduction in the rate of expansion of the hone from said predetermined rate, and means actuated by said control means for controlling said power actuated means.

13. The combination in a honing machine having an expansible and contractible hone, power actuated means for expanding the hone to exert a predetermined pressure on the work, means for automatically checking the rate of expansion of the hone, and means controlled by said checking means for increasing the pressure exerted by the hone on the work when the rate of expansion falls below a predetermined value.

14. The combination with pressure fluid operated means for feeding a metal removing tool to a work piece, shiftable abutment means for positively limiting the feed to a predetermined maximum rate, a device adapted to respond to a reduction in the feed rate from said predetermined maximum, and means actuated by said device upon responding to such reduction of the feed rate for regulating the pressure fluid operated means in a manner effective to restore the predetermined feed rate.

15. A control device for machine tools having power actuated means for feeding a metal removing tool to a workpiece, said control device comprising a pair of relatively movable members, means for moving one of said members at a rate proportional to the actual feed of the tool, means for moving the other of said members at a rate proportional to the desired feed of the tool, said members maintaining a predetermined relationship only while the actual feed rate of the tool substantially equals the desired feed rate, and means operative upon a change in said relationship in response to a lag of the actual feed rate of the tool for regulating the power actuated feed means.

16. The method of regulating the rate of expansion

of a honing tool during a honing operation which comprises, continuously comparing the actual rate of expansion of the hone with a standard indicating the desired rate of expansion, increasing the pressure on the hone sufficiently to partially break down the surface of the abrasive elements of the hone when the rate of expansion falls below the desired rate, and terminating the application of increased pressure before the abrasive elements are damaged.

17. The combination with means for applying a force to expand a honing tool, of a movable member, means for moving said member at a rate proportioned to the actual rate of expansion of the tool, a second member supported for movement relative to said first member, means for moving said second member at a rate proportioned to a desired rate of tool expansion, said members maintaining a predetermined relationship as long as the actual rate of tool expansion coincides with the desired rate, and means operative in response to a change in the relationship of said members due to a lag in the actual rate of tool expansion for applying additional expanding force to the tool.

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