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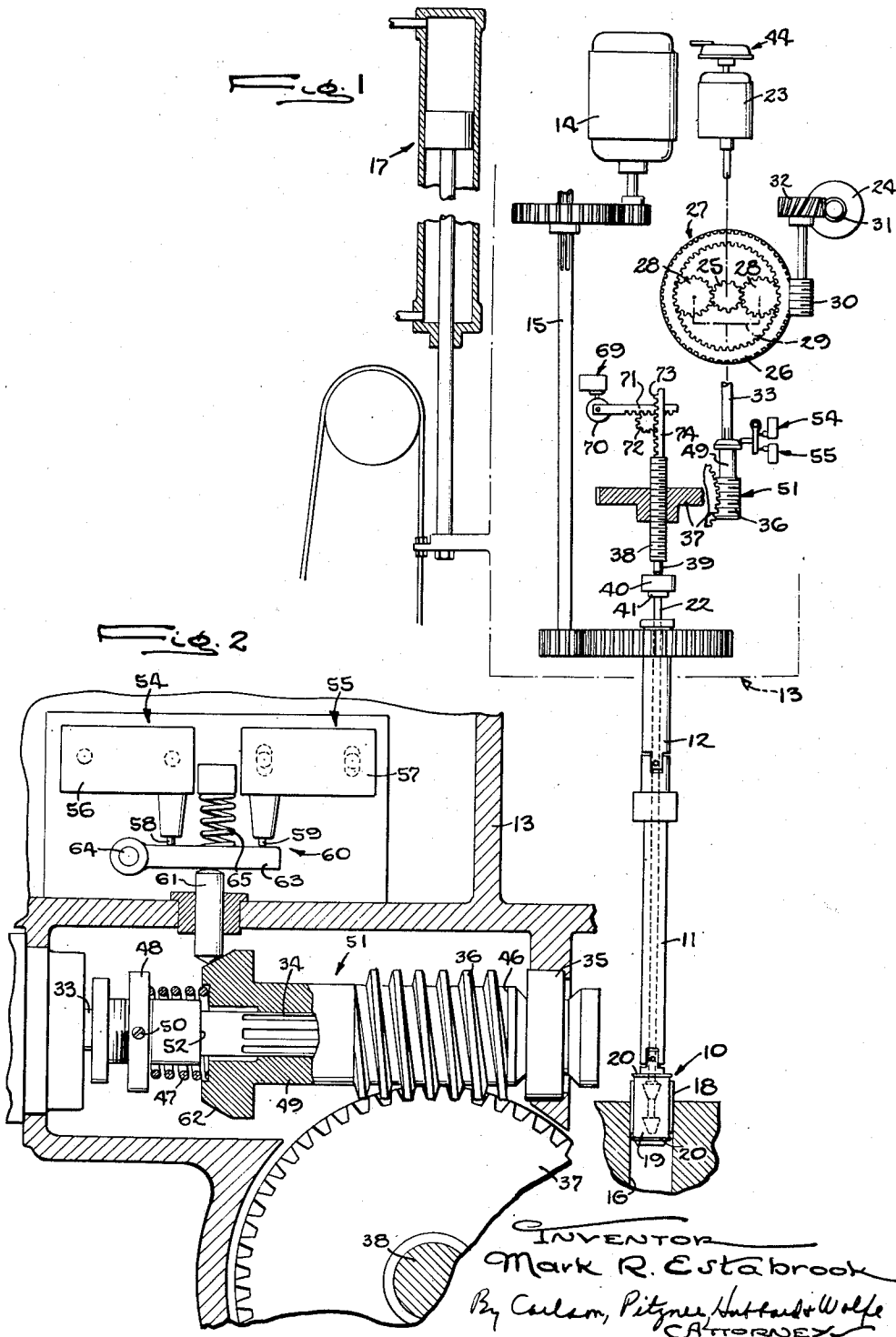
M. R. ESTABROOK

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HONING MACHINE

Filed March 18, 1955

2 Sheets-Sheet 1



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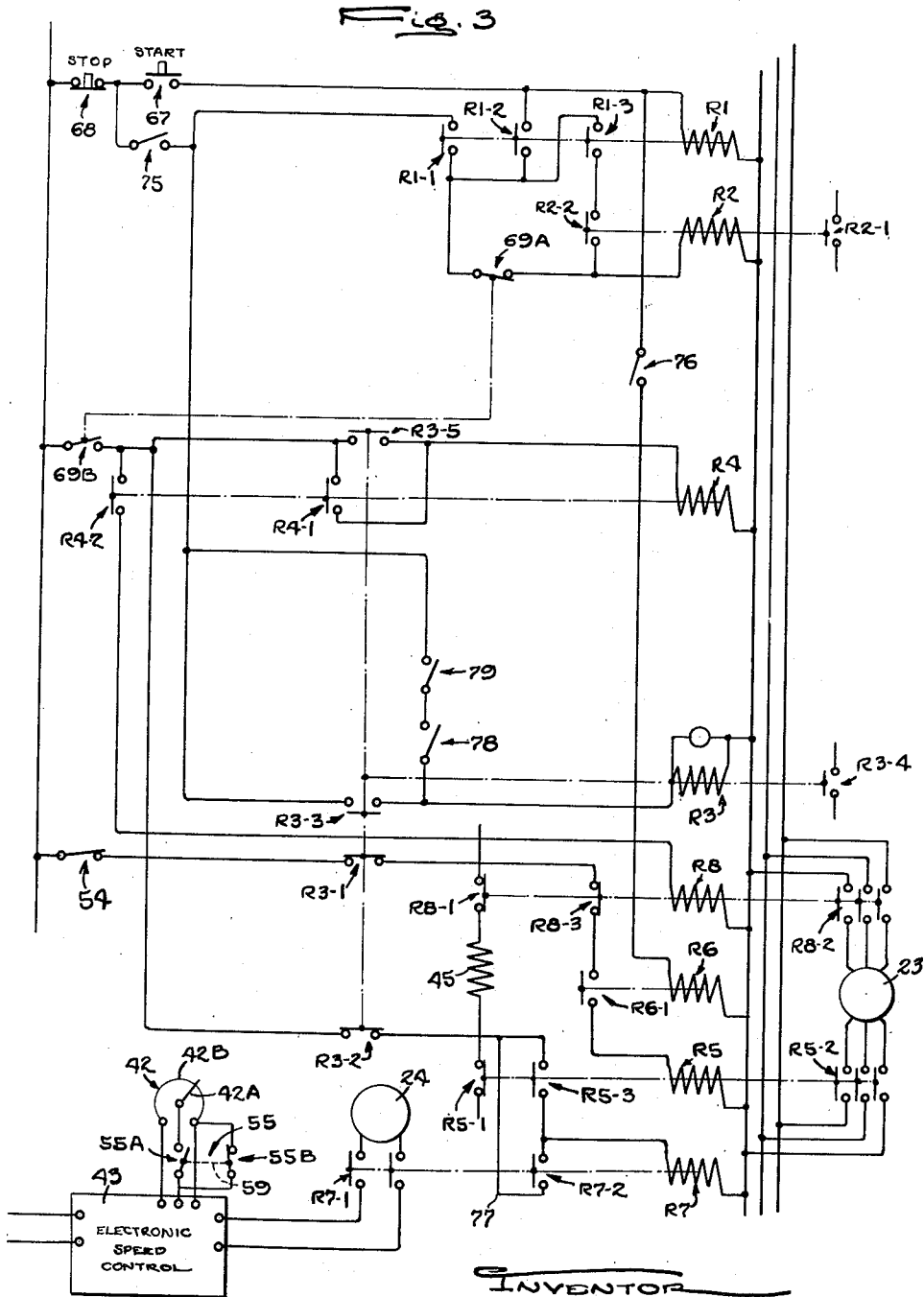
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1

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HONING MACHINE

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Application March 18, 1955, Serial No. 495,301

7 Claims. (Cl. 51-184.3)

This invention relates generally to honing machines in which, after its entry into a work bore, the hone is expanded first rapidly into engagement with the bore wall and then at a controlled slow rate during enlargement of the bore. More particularly, the invention relates to hone expanding mechanism of the type disclosed in an application of Ernest Y. Seborg and Donald K. Greenberg, Serial No. 340,232, filed March 4, 1953, in which the hone expander is connected to the output member of a power operated drive mechanism through a yieldable lost motion and the speed of such output member is changed from fast to slow in response to shifting of a part of the connection upon the building up of a predetermined pressure on the honing elements after their engagement with the bore wall.

The primary object of the invention is to improve hone expanding mechanism of the above character and avoid the loss of time resulting from changing the speed of the output member of the drive mechanism from fast to slow before take-up of all of the slack in the lost motion connection.

Another object is to achieve the foregoing object by reduction of the speed of the output member from its fast value to a slow intermediate value in response to the taking up of a part of the slack in the lost motion connection thereby permitting accurate sensing of the take-up of all of the slack for changing the speed of the output member to its slow value.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings, in which

Figure 1 is a schematic view of the head and tool of a honing machine embodying the novel features of the present invention.

Fig. 2 is a fragmentary sectional view taken through the head and showing parts of the hone expanding mechanism.

Fig. 3 is an electric circuit diagram.

The improved hone expanding mechanism is particularly adapted for use in production type honing machines in which the honing tool 10 is carried on the lower end of a jointed shank 11 coupled to a spindle 12 which is journaled in a hollow head 13 reciprocable vertically on a frame (not shown). Rotation of the spindle is effected by an electric motor 14 mounted on the machine frame and driving a splined shaft 15 geared to the spindle. To raise and lower the head for entry and removal of the collapsed hone into and out of the work bore 16 and for reciprocation of the expanded hone within the bore, a hydraulic actuator 17 mounted on the frame is connected to the head and is supplied with pressure fluid in a manner well known in the art, for example, as shown and described in detail in the aforementioned application of Seborg et al.

The honing tool 10 comprises a series of stones 18 spaced angularly around a body 19 and normally held by garter springs 20 against conical cams 21. The latter

2

are fast on a rod 22 which extends upwardly through the hollow tool shank 11 and spindle 12. When the rod is moved downwardly, the stones 18 are expanded against the wall of the bore 16, the outward pressure on the stones being continued while the spindle is rotated and reciprocated to enlarge the bore to the desired size.

Power operated drive mechanism for expanding the hone 10, in this instance, comprises two electric motors 23 and 24 mounted on the head 13 and coupled to the terminal members 25 and 26 of a planetary type differential gearing 27. The shaft of one motor 23 carries the sun gear 25 of the differential, this gear meshing with angularly spaced planet gears 28 whose shafts are journaled on the spider or intermediate member 29 of the differential. The ring gear 26 meshes with the planet gears and, on its outer periphery, is toothed to constitute a worm wheel meshing with a worm 30 which is connected to the shaft of the other motor 24 through another worm 31 and worm wheel 32, the two worm gearings providing a substantial reduction in the speed of the motor as applied to the differential.

The spider 29 of the differential is fast on one end of an output shaft 33 whose other splined end portion 34 is supported in a bearing 35 (Fig. 2) and carries a worm 36 meshing with a worm wheel 37 journaled on the head for rotation about a vertical axis. The wheel is threaded internally and forms a nut for a screw 38 on a shaft 39 slidable endwise along the axis of the expander rod 22 but held against turning relative to the head. At its lower end, the screw shaft bears against a slidable plug 40 supporting the upper end of the expander rod in a thrust bearing 41.

It will be apparent from the foregoing that the rotary motions of the motors 23 and 24 are combined by the differential 27 to produce rotary motion of the output shaft 33 and, after a further speed reduction by the worm gearing 36, 37 and the nut and screw 37, 38, are converted to reciprocatory motion of the expander rod 22. The gear ratios are such that, when both of the motors are operating in a direction to move the rod downwardly, the hone expands at a comparatively rapid rate such as .047 of an inch per second. On the other hand, operation of the motor 24 alone, when the sun gear 25 is held against rotation produces expansion at a much slower rate, for example, .00019 of an inch per second, the latter rate corresponding approximately to the rate of wearing off of one type of honing stone and work material. Variation of the rate of slow expansion may be obtained by manual adjustment of the effective value of a potentiometer 42 (Fig. 3) forming a part of a speed regulator 43 which controls energization of the motor 24 and may be an electronic unit commonly sold under the trade name of Thymotrol. The sun gear preferably is held against rotation each time the motor 23 is deenergized by a suitable brake 44 which may be of the electromagnetic friction type having a stator including a winding 45 and operable, when the winding is energized to apply a retarding torque to the shaft 15 of the motor, the winding being energized and deenergized respectively when the motor is deenergized and energized.

Rapid contraction of the hone 10 occurs when the fast motor 23 is operated in the opposite direction either alone or with the slow motor 24. In this case, the expanding rod 22 is raised and, as the cams 21 retract, the honing elements 18 are collapsed by the garter springs 20.

Termination of the rapid expansion movement of the honing stones 18 and continued expansion at the slow rate is effected in response to shifting of the worm 36 axially of its shaft 33 upon engagement of the stones with the wall of the work bore 16. Normally, the worm is urged axially against a stop 46 (Fig. 2) abutting the bearing 35 by a coiled spring 47 encircling the shaft and

3

acting between a collar 48 threaded on the shaft and one end of a sleeve 49 journaled on the shaft and abutting at its other end against the worm. By release of a locking screw 50 and turning of the collar, the stress of the spring 47 may be adjusted to vary the torque in the connection 51 between the differential output shaft 33 and the expander rod 22 or the pressure on the stones at which the worm 36 starts to yield. A stop shoulder 52 on the shaft abuts the sleeve 49 to limit the yielding movement of the worm against the action of the spring.

In hone expanding mechanisms of the above character, it is desirable to interrupt the rapid expansion movement before the stones 18 are subjected to a crushing pressure but, at the same time, to avoid any loss of time resulting from initiation of the slow expansion movement before the slack in the yielding lost motion connection 51 is taken up by abutment of the sleeve 49 with the shoulder 52. This is accomplished in accordance with the present invention by reduction of the speed of the output shaft 33 first from its rapid expansion value to an intermediate value in response to initial engagement of the stones with the wall of the work bore 16 as evidenced by shifting of the worm 36 away from the stop 46 to take up a part of the slack in the yielding connection. Then, in response to detection of the take-up of all of the slack upon abutment of the sleeve 49 with the stop shoulder 52, the speed of the output shaft is reduced further to its slow expansion value, the intermediate speed permitting accurate sensing of the take-up of all of the slack while reducing the time required for such take-up. Where the fast and slow expansion speeds are on the order of those given above, the intermediate speed of the shaft may be that which corresponds to a hone expansion rate of approximately .00066 of an inch per second and is several times the speed of the shaft for the slow expansion rate of .00019 of an inch per second.

While rotation of the output shaft 33 at the intermediate speed may be effected in various ways, the motion for such rotation is derived in this instance from the slow motor 24. To signal engagement of the stones 18 with the bore wall 16 and reduce the output shaft speed, shifting of the worm 36 away from the stop 46 is utilized to actuate a switch 54 located in the energizing circuits for the motors 23 and 24 to deenergize the fast expansion motor and energize the brake winding 45 (Fig. 3) so as to transfer control of the hone expansion to the slow motor for rotation of the output shaft at the intermediate speed. Further shifting of the worm to bring the sleeve 49 into abutment with the stop shoulder 52 is utilized to actuate a second switch 55 which changes the energizing circuits of the slow motor to reduce the speed of the output shaft to its slow value.

In this instance, the second or slack responsive switch 55 comprises normally open contacts 55A connected in series with the slider 42A of the potentiometer 42 and normally closed contacts 55B connected in a shunt around the slider and to one terminal of the potentiometer resistance element 42B. When the contacts are in their normal conditions, the speed setting of the potentiometer is at its constant maximum value. When the switch is actuated, the contacts 55A close and the contacts 55B open to render the slider effective to determine the speed of the motor 24 for slow expansion of the hone 10.

The contacts of the switches 54 and 55 are housed within suitable casings 56 and 57 mounted on a partition of the head for movement of the switch actuating pins 58 and 59 through a connection 60 with the worm 36. This connection includes a follower plunger 61 slidable in the partition and engaging a cam surface 62 on the sleeve, the mounting of the second switch 55 permitting adjustment of its casing 57 relative to the partition. To insure accurate sensing of abutment of the sleeve 49 with the stop shoulder 52, it is preferred to multiply the motion of the plunger 61 before it is applied to the pin 59 of the second switch as by a lever 63 between the two.

4

Herein, the lever is a straight bar fulcrumed at one end on a pivot 64 on the partition and extending between the actuating pins and the plunger. The latter abuts the bar intermediate its ends and the second actuating pin 59 abuts the bar adjacent its end remote from the pivot, the first actuating pin 58 engaging the bar between the pivot and the plunger. A spring 65 acting between the partition and the lever urges the plunger 61 yieldably against the cam surface 62.

When the worm 36 is in its normal position against the stop 46 so that the slack in the lost motion connection 51 is taken up in one direction, the plunger 61 engages a low point on the cam 62 thus allowing the first switch 54 to remain closed and the second switch 55 to remain in its normal condition with the contacts 55A open and the contacts 55B closed. In the initial yielding of the spring 47 following engagement of the honing stones 18 and the work bore 16 and partial take-up of the slack in the opposite direction, the plunger is shifted outwardly and, acting through the lever 63, opens the first switch 54. The latter, along with the second switch contacts 55A, remains open and the switch 55B remains closed until the remainder of the slack is taken up by movement of the sleeve 49 with the worm and against the stop shoulder 52. By proper adjustment of the position of its casing 57 and actuating pin 59, the second switch contacts 55A and 55B are closed and opened respectively at substantially the same instant the sleeve abuts the shoulder.

Operation

Energization and deenergization of the power operators 23 and 24 for expanding and contracting the hone 10 occur at proper times in the automatic cycle of the honing machine governed by well known mechanism such as that disclosed in the aforementioned Seborg et al. application and including the control circuits of Fig. 3. After a cycle has been completed, the control circuits are conditioned as shown in Fig. 3 with the spindle drive motor 14 stopped and the supply of pressure fluid to the hydraulic actuator 17 shut off by interruption of a circuit at contacts R2-1 of a relay R2, the latter also operating to energize the spindle drive motor. Both hone expansion motors 23 and 24 are deenergized and the brake winding 45 is energized through contacts.

After a new workpiece has been clamped in a fixture on the machine, a start switch 67 is closed manually to complete a circuit across A. C. power lines for energizing a relay R1 through a normally closed stop control switch 68. The resulting closure of contacts R1-1 completes a circuit for energizing the relay R2, this circuit extending through the contacts R1-1 and contacts 69A of a switch 69 (Fig. 1) which is positioned on the head 13 for actuation by a roller 70 (Fig. 1) carried by a rack bar 71 meshing with a pinion 72. The latter meshes with rack teeth 73 formed on an extension 74 of the screw shaft 39, endwise motion of the expander rod 22 to its upper limit position thus being utilized to close the contacts 69A when the hone is fully collapsed and to open the contacts when the rod starts its downward movement to expand the hone.

Energization of the relay R2 closes its contacts R2-1 thereby completing a circuit for supplying pressure fluid to the hydraulic actuator 17 and the initiation of downward movement of the head 13. In the first part of this movement, a switch 75 is closed to complete a holding circuit for the relay R1 through contacts R1-1 and R1-2 and the stop switch 68, and also, a holding circuit for the relay R2 through the then closed contacts R1-1, R1-3 and R2-2. Operation of the switch 75 and also of switches 76 and 79 referred to below is effected in response to movements of the head 13 in a manner described in the aforementioned application of Seborg and Greenberg.

When, in the continued downward movement of the head 13, the honing tool 10 reaches the lower end of

5

the work bore 16, a switch 76 is closed, this switch remaining closed while the tool reciprocates within the work bore and opening upon withdrawal of the tool from the bore. Through the then closed switches R1-2, R1-1, and 75, the switch 76 completes a circuit in parallel with the relay R1 for energizing a relay R6 thus closing contacts R6-1 by which a relay R5 is energized through a circuit including the then closed torque responsive switch 54 described above and closed contacts R3-1 of a then deenergized relay R3. The relay R5 then opens contacts R5-1 to deenergize the winding 45 and thus release the brake 44 and also closes contacts R5-2 for energizing the high speed motor 23 to run the latter in a direction to shift the rod 22 downwardly and expand the hone 10 rapidly.

In the initial part of the ensuing downward movement of the expanding rod 22, the contacts 69A of the switch 69 are opened by withdrawal of the roller 70 (Fig. 1) and companion contacts 69B are closed, the latter completing a circuit for energizing a relay R7 through normally closed contacts R3-2 of the relay R3 and contacts R5-3 then closed by the relay R5. Such energization of the relay R7 closes contacts R7-1 for energizing the slow expansion motor 24 and also completes a holding circuit for the relay by closure of contacts R7-2. The motor 24 thus is energized for rotation at its faster speed with the switch 55 in its normal condition and the maximum speed setting of the potentiometer 42 effective in the energizing circuits for the motor.

With the motors 23 and 24 both operating, the output shaft 33 rotates at its fast speed to shift the rod 22 downwardly and expand the honing tool 10 to the full size of the work bore 16 in a small fraction of a second. As soon as the rapidly expanding stones 18 encounter the bore wall, the pressure thereon and the torque in the driving connection 51 build up quickly. When such torque attains a value sufficient to overcome the spring 47, the worm 36 and the sleeve 49 shift axially and, in their initial movement, open the switch 54 thereby interrupting the holding circuit for the relay R5 which is deenergized to open the contacts R5-2 for stopping the fast motor 23 and to close the contacts R5-1 to energize the brake winding 45. The fast motor thus is stopped abruptly before the honing stones 18 have been subjected to substantial pressure. The operation of the slow motor 24 for rotation of the output shaft 33 at its intermediate speed continues by virtue of the holding circuit for the relay R7 which extends through the contacts R7-2 and a conductor 77 by-passing the contacts R5-3.

Rotation of the output shaft 33 at its intermediate speed continues until all of the slack in the drive connection 51 is taken up by abutment of the sleeve 49 with the stop shoulder 52. Such take-up is signaled by actuation of the switch 55 which changes the speed setting of the potentiometer 42 to the preselected slow value. The motor 24 then operates to rotate the output shaft 33 and continue expansion of the stones 18 at the slow rate while the hone is reciprocated back and forth through the work bore 16.

Termination of the honing operation by contraction of the stones and withdrawal of the tool from the bore when the latter reaches the desired diameter may be effected in various ways as by a suitable gaging device (not shown) adapted to measure the bore and close a switch 78 when the bore reaches the predetermined finish size.

Upon closure of the sizing switch 78 and a switch 79 which is closed at the end of each down stroke of the honing head 13, a circuit for energizing the relay R3 is completed through the stop switch 68 and the head actuated switch 75. The energization of this relay is maintained through sealing contacts R3-3 in a circuit by-passing the sizing switch 78 and the switch 79 and results in

6

closure of contacts R3-4 to establish circuits controlling the pressure fluid system for effecting withdrawal of the tool from the bore 16. Also, contacts R3-1 and R3-2 are opened to interrupt the circuit through the torque switch 54 and the circuit for the relay R7, thereby deenergizing the latter and the slow motor 24. Other contacts R3-5 of the relay R3 are closed to complete a circuit through a collapse relay R4, the stop switch 68, and the head actuated switch 75. Upon energization of the collapse relay R4, a holding circuit for the same is completed at contacts R4-1, and contacts R4-2 close to complete a circuit through the then closed expander rod switch 69B and a relay R8. The latter opens the circuit for the brake winding 54 at contacts R8-1 to release the brake 44 and closes contacts R8-2 for energizing the fast motor 23 to run the latter in a direction to raise the expander rod 22 and collapse the hone. Other contacts R8-3 open to insure interruption of the circuit for the relay R-5 which controls the circuits for rotation of the fast motor in the expanding direction.

In the initial reverse turning of the worm 36, the spring 47 shifts the sleeve 49 to permit the torque switch 54 to close and the slack responsive switch 55 to return to its normal condition. When the expander rod 22 reaches its upper fully collapsed position, the switch 69B is opened by the roller 70 thereby interrupting the circuit to the collapse relay R4 and the relay R8 to deenergize the fast motor. Normally, collapse by the rapid action of the motor 23 is completed substantially instantaneously and well before the hone passes out of the work bore. The withdraw relay R3 remains energized until the head 13 has been raised far enough to withdraw the collapsed hone completely from the bore 16 as indicated by opening of the switch 75. The head then comes to rest and the circuits are conditioned for the start of the next cycle which may be initiated by again closing the manual switch 67 after a new workpiece has been placed in the machine fixture.

The improved hone expanding mechanism above described makes it possible to expand the stones 18 against the bore wall 16 at a rapid rate and continue the expansion at a slow controlled rate substantially instantaneously and without subjection of the stones to a crushing pressure. By reduction of the speed of the output shaft 33 to an intermediate value, it is possible not only to take up the slack in the drive connection quickly, but also, to sense such take-up accurately. As a result, valuable time previously lost in taking up slack at the slow speed of the output shaft is avoided thereby affording a greater production capacity of the honing machine.

I claim as my invention:

1. In a honing machine, the combination of an expandable honing tool having abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member coupled to said elements and mounted on said head for movement relative thereto to expand said tool, electrically actuated drive means having an output member and selectively operable to move the member at predetermined fast, intermediate, and slow speeds, a connection between said members including a part yieldably urged into a first position and movable into a spaced position in response to the building up of a predetermined expansion pressure on said elements after engagement of the same with said bore wall, a switch actuated in response to movement of said part out of said first position and operable when actuated to change the energization of said drive means and cause movement of said output member at said intermediate speed, a second switch mounted on said head and operating when actuated to produce a further change in the energization of said drive means and cause movement of said output member at said slow speed, and a motion multiplying connection between said part and said second switch operating to actuate the latter in response to movement of the part into said spaced position thereof.

2. In a honing machine, the combination of, an expandable honing tool having abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member coupled to said elements and mounted on said head for movement relative thereto to expand said tool, fast and slow electric motor operators, rotary drive mechanism coupling said operators to said member, circuits controlling energization of said operators for producing predetermined fast, intermediate and slow speeds of said member in a hone expanding direction, said mechanism including a part yieldably urged into a first position and movable into a spaced position in response to the building up of a predetermined torque in said mechanism, a first switch in said circuits operable in response to movement of said part out of said first position to effect interruption of the operation of said fast operator and to energize said slow operator alone to move said member at said intermediate speed, and a second switch in said circuits operable in response to movement of said part into said spaced position to change the degree of energization of said slow operator and cause movement of said member at said slow speed.

3. In a honing machine, the combination of, an expandable honing tool having abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member coupled to said elements and mounted on said head for movement relative thereto to expand said tool, electric motor operators, rotary drive mechanism coupling said operators to said member, circuits controlling the degree of energization of said operators for producing predetermined fast, intermediate and slow speeds of said member, said mechanism including an element yieldably urged into a first position and movable away from the same and toward and into a spaced second position in response to the build up of a predetermined torque in said mechanism following engagement of the expanding honing elements with said work bore, and two switches controlling said circuits and operable to vary the degree of energization of said operators in response to movement of said element respectively to change the speed of said member from said fast speed to said intermediate speed upon movement of element out of said first position and to cause movement of the member at said slow speed after movement of the element into said second position.

4. In a honing machine, the combination of, an expandable honing tool having movable abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member connected to said elements and mounted on said head for movement relative thereto to expand said tool, power operated drive means including a rotary output member and selectively operable to rotate the latter at predetermined fast, intermediate and slow speeds, a connection between said members for expanding said tool upon rotation of said output member, said connection including a part yieldably urged into a first limit position and movable toward and into a second position in response to the building up of a predetermined torque in the connection after engagement of the expanding honing elements with said bore wall, and mechanism controlling said drive means in response to movement of said element and including a first device for changing the speed of said output member from said fast speed to said intermediate speed in response to initial movement of said element out of said first position and a second device for changing the speed of the output member from said intermediate speed to said slow speed in response to movement of the element into said second position.

5. In a honing machine, the combination of, an expandable honing tool having movable abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member connected to said elements and mounted on said head for movement rela-

tive thereto to expand said tool, power operated drive means including an output member and selectively operable to move the latter in a hone expanding direction at predetermined fast, intermediate and slow speeds, a connection between said members including an element yieldably urged into a first limit position but movable from the latter toward and into a second position in response to the building up of a predetermined expanding pressure on said elements after engagement of the latter, while expanding, with said bore wall, means controlling said drive means and operating in response to initial movement of said element out of said first position to change the rate of movement of said output member from said fast speed to said intermediate speed, and additional means controlling said drive means and operating in response to movement of said element into said second position to change the rate of said output member from said intermediate speed to said slow speed.

6. In a honing machine, the combination of, an expandable honing tool having movable abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member connected to said elements and mounted on said head for movement relative thereto to expand said tool, power operated drive means including an output member and selectively operable to move the latter in a hone expanding direction at predetermined fast, intermediate and slow speeds, a connection between said members including lost motion of which the slack is taken up yieldably in one direction during expansion of said elements toward said bore wall and is taken up in the opposite direction in response to the building up of a predetermined expanding pressure on said elements after engagement of the elements, while expanding, with said bore wall, first mechanism for sensing the take up of a part of said slack in said opposite direction, second mechanism for sensing the take up of all of said slack in said opposite direction, and means controlling said drive means and operating to change the speed of said output member from said fast speed to said intermediate speed in response to said first mechanism and from said intermediate speed to said slow speed in response to said second mechanism.

7. In a honing machine, the combination of, an expandable honing tool having movable abrasive elements engageable with the wall of a work bore, a head supporting said tool, means including a member connected to said element and mounted on said head for movement relative thereto to expand said tool, power operated drive means including an output member and selectively operable to move the latter in a hone expanding direction at predetermined fast, intermediate and slow speeds, a connection between said members including lost motion of which the slack is taken up yieldably in one direction during expansion of said elements toward said bore wall and is taken up in the opposite direction in response to the building up of a predetermined expanding pressure on said elements after engagement of the elements, while expanding with said bore wall, means controlling said drive means and operating in response to take up of a part of said slack in said opposite direction to change the rate of movement of said output member from said fast speed to said intermediate speed, and further means controlling said drive means and operating in response to the take-up of all of said slack in said opposite direction to change the rate of movement of said output member from said intermediate speed to said slow speed.

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