This invention relates to honing machines of the multiple spindle type for honing a plurality of parallel cylinders simultaneously during relative reciprocation between the workpiece and a single head carrying all of the honing tools. The invention has more particular reference to multiple honing machines in which the collapse of each hone is effected individually and automatically under the control of a sizing device which responds to changes in the size of the cylinder being honed and controls the expanding mechanism of the hone to release the pressure on the stones and permit collapse of the hones when a predetermined size has been obtained.

In certain honing operations, it is desirable after the work surface has attained a certain size predetermined by an associated size measuring device to continue the reciprocation of the honing tool for a few strokes while the abrasive elements thereof are pressed against the work surface. Usually such supplemental honing or so-called "sparking out" is performed under lesser pressure than that used during the primary honing.

The primary object of the invention is to provide a multiple spindle honing machine having a novel mechanism for controlling the supplemental honing by the several hones to avoid any possibility of leaving the finished surfaces marred.

A further object is to effect the supplemental honing by the several hones through a single timing control mechanism, thus minimizing the cost and complexity of the controls.

The invention also resides in the novel manner of utilizing the sizing signals in controlling the mechanism of the hones to effect the supplemental honing while at the same time insuring that all of the different bores will be finished to precisely the same size.

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 fragmentary front elevational view of a four spindle honing machine adapted to be controlled in accordance with the present invention.

Fig. 2 is a schematic view of the main actuators and their controls.

Fig. 3 is a wiring diagram of the controls for one of the tool units.

Fig. 4 is a wiring diagram of the interrelated controls for all of the spindles.

The improved supplemental honing control is shown in the drawings in a four spindle production type machine having four tools 10, 10a, 10b, 10c rotatable about parallel axes laterally spaced for the simultaneous honing of bores 11, 11a, 11b, 11c in a workpiece 12 while the latter is supported in a suitable fixture. The hones are carried by the lower ends of jointed shanks 13 coupled to spindles 14 journaled on and projecting from a hollow head 15 which is slideable back and forth on guide rods 16 rigid with the machine frame. A motor 17 (Fig. 2) mounted on the frame drives the respective spindles through separate gear connections. Raising and lowering of the head 15 to enter the collapsed hones into or to remove the same from the work bores and to reciprocate the expanded hones within the bores may be effected by a hydraulic actuator 19 mounted on the machine frame and supplied with pressure fluid from a motor driven pump 20 under the control of a reversing valve 21. Actuation of the latter is controlled by a pilot valve 62 whose actuating rod 63 is urged by a spring 64 toward the position shown in Fig. 2 to move the tool head downwardly. Reversal of the valve position may be effected by energization of a solenoid 65 or by a cam 66 on an arm 67 loose on the shift of a cam dial 68 which through a connection 69 with the hone actuator 19 is oscillated back and forth with the up and down movements of the tool head 15.

Each honing tool comprises a series of stones 22 angularly spaced around a body 23 and normally held as by the usual garter springs against conical cams 24. The latter are fast on a rod 25 which extends upwardly through the hollow tool shank and spindle 12. When the rod is moved downwardly, the stones 22 are expanded against the wall of the bore, the outward pressure on the stones being continued while the spindle is rotated and reciprocated to enlarge the bore to the desired size.

Reciprocation of the rods 25 to expand and allow contraction of the hones may be effected by various types of power actuators, the one shown here for purposes of illustration being of the type forming the subject matter of Soboerg et al. application Serial No. 340,232, filed March 4, 1955, to which reference is hereby made for further details. Each actuator indicated generally 27 is mounted on the tool head 15 and comprises two electric motors 28 and 29 respectively coupled through appropriate gearing with the terminal elements 30 and 31 of a differential gear 33 hereinafter referred to as the planetary gear. The spider or intermediate member 34 carrying the planet gears is coupled through speed reduction gearing including a worm 35 to a nut 32 journaled on the head 15 and threaded onto a screw 36 on the expander rod.

It will be apparent that the rotary motions of the motors 28 and 29 can be combined by the differential 33 and, after a further speed reduction, are reversed into reciprocatory motion of the expander rod 25. The gear ratios are such that when both of the motors are operating in a direction to move the rod downwardly, the diameter of the hone 18 will be increased at a comparatively rapid rate, for example, 0.05 of an inch per second.

On the other hand, when the motor 29 alone is operating, the diameter of the hone will be increased at a much slower rate, for example, 0.0002 of an inch per second.

This slow rate is variable by manually adjusting the knob 38 (Fig. 3) of a speed regulator 39.

Rapid contraction of the hones will occur when the fast motor 28 is operating in the opposite direction either alone or with the motor 29 thus raising the expanding rod 25. As will appear later, the maximum extent of such collapse of each hone is limited by opening of a switch 15 by movement to the position shown in Fig. 2 of a rack bar 60 meshing with a pinion 61 which in turn meshes with rack teeth on the upper end of the screw 36. Each of the switches 15 is associated with a switch 28 which is open when the associated hone is fully collapsed but closed at all other times. Quick stopping of the sun gear 30 abruptly when the motor 28 is deenergized is effected by a magnetically applied brake 40 coupled to the motor shaft and connected in the motor circuit so as to be released whenever the motor is energized.

Means is provided for signaling the engagement of the honing stones with the bore wall during the rapid expansion of the hone and thereupon interrupting the
circuit for the winding of the higher speed power actuator, the slower speed actuator continuing to operate to expand the stones during actual honing of the bores. Herein, the winding means includes a switch 3S (Fig. 2) actuated by a device which is yieldable in response to the building up of a predetermined torque in the drive connection to the hone expanding cams. The yielding device shown includes the worm 37 (Fig. 2) whose supporting shaft 42 is urged against a stop 43 by a spring 44. When the torque being transmitted to the worm when exceeded a comparatively low value, the spring 44 yields and permits the worm to shift axially whereupon a cam 45 actuates the follower pin of the switch 3S, the latter controlling the stopping of the motor 28 and the application of the brake 40 as will appear later.

Associated with each hone 10 is a device 50 for feeling of the bore as it is being enlarged, sensing the attainment of the desired size and, in response to such signal, initiating release of the expanding pressure or collapse of the hone to discontinue its ablading action. The size measuring device herein shown forms the subject matter of an application of James B. Klein, Serial No. 325,257, filed December 11, 1952. It comprises a plug or gauge ring 51 on the lower end of a sleeve 52 surrounding the tool shank 13 and mounted on a bracket 53 (Fig. 1) for limited free floating laterally in a bore of the tool axis, and urged downwardly by a spring 54. Each of the rings is beveled at its lower end and sized to enter the bore when the latter has been enlarged to the proper size.

Through rods 55 having stops 56 thereon and slideable in ears 57 on the head 15, the bracket 53 is urged from the head so as to move with the head during most of its down stroke and after the hone or the hone have entered the bores, the beveled ends of the plugs then contacting and becoming seated in the upper ends of the bore walls. After the sleeve thus stops in feeling engagement with the bore, the tool head and the hones continue on to the end of the down stroke, the ears 57 sliding down along the rods 55 in this first part of the down stroke of the heads. In this position of the plug, an arbor 58 (Fig. 2) on the sleeve is stopped short of contact with the actuating pin of a switch 59 stationarily mounted on the fixture supporting the workpiece.

When, by the action of the hone, any one of the bores has been enlarged to a diameter corresponding to the size of the plug 51, the latter will enter the end of the bore in the latter part of the down stroke of the tool head. The arm 58 thus moves far enough to engage and actuate the switch 59 whose design signals the attainment of the desired bore size. It will be observed that each of the sizing devices 50 operates independently of the others and feels of its bore during each down stroke of the tool head but fails to enter the bore until the latter has been enlarged to the desired diameter.

In the honing of a multiple bore workpiece with a machine of the above character, the reciprocation of the tool head 15 is continued until all of the bores have completed their respective bores, each hone being collapsed when its bore comes up to size as determined by its associated sizing device 50. The present invention contemplates a novel interrelation of the controls for the several hone expanders 27 to provide for substantially equalized supplemental honing or "sparking out" of all of the bores, preferably under light pressure in spite of the completion of the primary honing of the several bores at different times for any one workpiece and in different workpieces in successive workpieces.

Generally stated, the improved control provides for collapsing each hone when its work bore comes up to size and maintaining each hone collapsed until all have completed the primary honing of the respective bores, then expanding all of the bores in response to the signal from the sensing device of the last bore to be finished, the supplemental honing by all of the tools then continuing for the required short interval so as to leave all of the bores with a fine finish and unmarked in any way. After the supplemental honing has continued for a measured interval, all of the hones are collapsed and withdrawn simultaneously from the bores by upward movement of the tool head.

The desired light pressure of the honing stone against the bore walls during the supplemental honing is achieved by effecting this expansion only by the motor 28 whose stopping is controlled by the torque responsive switch 3S. All of the hones may thus be brought into contact with the bore walls under light pressure determined by the adjustment of the torque sensing device. Preferably, provision is made for only partially collapsing each hone in response to the signal from its associated sizing device 50.

Typical circuitry for controlling the execution of a cycle of the above character is shown in Figs. 3 and 4, the former showing the complete circuit for one honing tool with the addition of certain relays and switches which are duplicated for the other tools and respectively indicated by postscripts a, b, and c. For example, the collapse indicating switches of the four tools are 2S, 25a, 25b, and 25c respectively. Also, the switches actuated by any relay are indicated by the same reference character with the addition of numerical postscripts, for instance 1R2 being the relay 1R. The rectangles shown in Fig. 4 represent those parts of Fig. 3 which are duplicated for the different tools. The time delay relays 8R and 11R are of various well known constructions and adapted, when energized, to measure an adjustable time interval and then actuate associated switches, the relay being reset automatically when deenergized. Let it be assumed that the parts are positioned as shown in Figs. 2, 3, and 4 with all relays and solenoids deenergized, the tool head 15 fully retracted upwardly, and all of the hones collapsed, this latter condition being evidenced by closure of the switches 1S, 1Sa, 1Sb, and 1Sc in the fully retracted position of the expander rods 2S, 25S, 25b, and 25c.

To start the next cycle after a new workpiece has been fastened in the fixture, the start button 70 is depressed to energize a relay 1R through the then closed switch 2R1. The resulting closure of the switch 1R1 energizes the relay 3R through switches 70, 1R1, 1S, 1Sa, 1Sb, and 1Sc thereby energizing a relay 3R which closes its switch 3R2 to reverse a valve 72 and direct pressure fluid through the pilot valve to the right end of the pilot valve 21. The latter is shifted to admit pressure fluid to the upper end of the actuator 19 and thus initiate downward movement of the tool head 15. In the initial clockwise turning of the dial 68 at the start of this movement, a dog 73 allows a switch 4S to close thus completing circuits through switches 1R2, 1R3, and 3R1 for maintaining the relays 1R and 3R energized independently of the start switch and also of the 1S switches when the latter are opened later as the hones are expanded. In the downward movement of the tool head, the hones enter the work bores but remain collapsed until at the extreme end of the stroke a dog 75 on the dial 68 closes a switch 5S later to be described and also engages and shifts the arm 67 clockwise into engagement with a switch 6S which then remains closed during reciprocation of the tools back and forth in the work bore even though the arm 67 is oscillated back and forth by dogs 75 and 76. In each clockwise movement of the arm, the cam 66 rocks workpiece 77 to reverse the position of the pilot valve 62 and thus cause the valve 21 to reverse the connection and initiate upward movement of the tool head by the actuator 19. As the dial and the dog 76 swing the arm counterclockwise at the upper end of the working stroke, the cam 66 permits the spring 64 to shift the valve 62 back to the position shown in Fig. 2 thus starting the next downstroke. Such reciprocation of the tools back and forth continues until the end of the cycle and after all
of the bores are up to size and the supplemental honing has been completed as described later. Closure of the switch 65 as above described at the lower end of the first downstroke completes a circuit for energizing a relay 4R through switches 1R1, 1R2, and 4S closing switches 1R1 and 1R2. Through parallel conductors 79P, 79Q, 79R, and 79S (Fig. 4), closure of the switch 4R1 prepares the size measuring circuits later to be described which circuits include the switches 59, 59P, and 59Q of the respective sizing devices 59. Through conductors 78, 78A, 78P, and 78Q circuits are completed by the switch 4R2 through then closed switches 5R1, 5R1B, and 5R1C in the different expander units. The resulting energization of relays 6R of these units closes a multiple switch 80 thereof to start the associated motor 28. This relay in each unit also closes a switch 6R1 to complete a circuit for the relay 7R through a then closed switch 5RS. Upon being energized, the relay 7R becomes sealed by its switch 7R1 and by closure of its switches 7R2, the feed motor 29 of the unit is started.

By the combined action of the two motors 23 and 29 of each expanding unit, each hone is expanded rapidly thus causing the associated switch 1S and closing the companion switch 7S. Then when the stones of each hone come against the wall of its bore, the expander rod 28 is blocked and the resulting torque buildup in the drive connection causes the worm to shift axially against the action of the spring 43 until the switch 3S is opened thereby deenergizing the relay 6R to deenergize the fast motor 28 and apply its brake 40. The motor 29 continues to run by virtue of sealing the relay 7R through switches 7R1, 5R1, and 2S thus continuing the expansion of the hone but at the slow rate to produce the heavy stone pressure desired for the primary honing of the bore. All the hones are thus expanded and removed stock from their respective bores as they are reciprocated up and down in unison in the manner described above.

In the latter part of each downstroke of the tool head, the gage rings of the different units come into feeling engagement with the ends of the bores and failure of the rings to enter the bores causes the expansion of the hones to continue in the further reciprocation of the tool head. Assume now that the bore 11 is the first to be finished as evidenced by entry of the gage ring 51 and closure of the switch 59. This completes circuits for energizing a signal light 81 to indicate that the bore 11 is finished and also for two parallel relays 5R and 3R which are sealed through the switches 5R2 and 4S. The relay 6R is of the time delay type having a normally closed switch 8R1 which, after energization of the relay is opened after the lapse of a predetermined interval long enough only to permit partial collapse of the hone by its motor 28. Opening of the switch 5R1 by the relay 5R interrupts the sealing circuit of the relay 7R whose deenergization stops the slow motor 29 and the hone expansion. At the same time, the closure of the switch 5R3 completes a circuit through the then closed timer switch 6R1 and the switch 2S to energize a relay 9R which closes switches 62 to start the motor 29 in a direction to collapse the hone. Energization of this relay also opens the switch 9R1 later used in preventing energization of the relay 6R. Another switch 5R4 is also closed by the relay 8R.

The operation of the hone following termination of the primary honing 59 is as follows: if the pressure relief is insufficient to relieve the stresses in the expanding mechanism and therefore to relieve the pressure of the stones against the work, thus, the interval measured by the time delay relay 8R is very short so that the hone is collapsed only partially but sufficiently to disengage the stones from the walls. The collapse is terminated when the relay 8R opens its switch 8R1 thus deenergizing the relay 9R to open the switch 82. As before, the switch 82 is stopped abruptly by its brake.

The same functions are performed by the expanding mechanisms of the other three hones 10h, 10p, and 10q in response to the sizing signal or closure of the respective switches 59h, 59p, and 59q. Thus, each hone is partially collapsed as its bore comes up to size thus interrupting the abrading action of that hone even though other of the hones may continue with the primary honing of their bores. Each collapsed hone merely reciprocates idly in its bore with the stones out of active contact with the bore wall.

Finally, when the relays 5R of all four of the hones have become energized and irrespective of the order of such energization, the four switches 5R4, 5R4B, b, and c will be closed and closure of the last one of these completes a circuit including the switch 4S for energizing the two relays 10R and 11R, the latter being a time delay relay. When the relay 10R closes the switches 10R1, 10R1A, 10R1B, and 10R1C, the circuits are completed for energizing the respective relays 6R in the case of those hones which are already partially collapsed, these being the first three of the hones to have completed the primary honing of their bores. The resulting closure of the corresponding switches 80 thus starts the corresponding motors 28 to initiate reexpansion of those three hones.

In the case of the last hone to complete its primary honing, such reexpansion is delayed momentarily in order to insure that this hone will also be collapsed partially and the pressure of its stones on the bore wall definitely relieved. Such delay is achieved by the action of the switch 9R1 in holding the energizing circuit of the relay 6R of the fourth hone open until this hone has been partially collapsed, the switch 9R1 having been opened by the relay 9R when the latter initiated the collapsing operation of the motor 28 in response to energization of the relay 5R by the up-to-size signal by the last sizing device 59 to close its switch 59.

Now when the last hone to finish its primary honing does become partially collapsed as evidenced by opening of the switch 8R1 by the time delay relay 8R, the relay 9R will be deenergized and the switch 9R1 closed to permit energization of the relay 6R and closure of the switches 80 of this unit to initiate reexpansion of the fourth hone. There is therefore a delay between the start of the reexpansion for supplemental honing between the first three of the hones to finish their primary honing and the fourth or last hone to finish such honing. The time difference is so short, however, as to have no effect on the uniformity in the sizes of the final bores particularly in view of the light pressure to which the work is subjected during the supplemental honing which pressure is produced by the motors 29 and is limited by the adjustment of the torque responsive switches 5S.

The invention contemplates again using the mechanism that terminates the rapid expansion for the primary honing to interrupt the operation of each motor 28 and stop the reexpansion preparatory to the supplemental honing or "sparking out." This mechanism includes the torque responsive switches 3S of the different units each of which switches is opened when the associated honing stones encounter the bore wall and a predetermined torque builds up in the drive connection.

The time delay relay 11R common to all of the hones is adjusted to close its switch 11R1 at a time shortly after the reexpansion of all of the hones of the bores has been completed. At this time, all of the relays are expanded and running the reexpansion will have been deenergized thus closing switches 6R2, 6R2b, b, and c in series with the switch 11R1 thus completing a circuit for activating a timer 85 which, after a predetermined interval selected by adjustment of a knob 86, closes a switch 87. During this interval, the four hones, all of which are expanded into light contact with the walls of their respective bores, will be reciprocated back and forth and rotated to effect the supplemental honing of these walls.

After the expiration of the interval selected for supplemental honing, the switch 87 is closed to complete
a circuit for energizing a relay 12R thus closing a switch 12R1 which holds the relay energized and also a switch 12R2. The latter operates in conjunction with the switch 55 to close a circuit for a relay 13R whose energization closes a switch 13R1 to energize the solenoid 65 which, as before described, shifts the valve 62 and initiates the final upward movement of the hones from the work bores. The relay 13R also closes a switch 13R2 in each unit which, through the then closed switch 25 of that unit, reenergizes the relay 9R to close the switch 82 and start the rapid motor 28. This collapses the hone until, after full collapse, the switch 25 of that hone is opened to deenergize the relay 9R and stop the motor 28.

In view of the energization of the solenoid 65 when the honing head 15 now reaches the up-stroke position and the upward motion of the head is continued until the dog 73 on the dial 68 reaches the position shown in Fig. 2. At this point, the switch 4S is opened to interrupt the sealing circuits for all of the then energized relays, the cycle being terminated with the parts conditioned and positioned as shown in Figs. 2, 3, and 4.

It will be observed that the supplemental honing action by the different tools and under light pressure is effected through the use of the same actuators and controls that govern the primary honing, and this in spite of the fact that the primary honing operations by the different tools is completed at different times. A minimum of additional equipment is required by adapting the control for the simultaneous performance of the supplemental honing operations by the different tools, these operations being controlled by the single unit 85.

During the supplemental honing which extends over several reciprocations of the tool head, plugs 51 of the different sizing devices will enter the work bores at the end of each down stroke. However, in the next up-stroke, the stones, although under light pressure, will remove any mark that may have been left near the bore due to entry of the sizing plug. Any substantial or noticeable marring of the finished surface by the repeated engagement with the sizing plug during the sparking out is thus effectively avoided by the improved control.

Reference above to the "collapse" of the hone contemplates a release of the expanding pressure on the stones even though the latter may not move substantially away from the bore wall.

I claim as my invention: 1. A machine for honing a plurality of parallel bores in a workpiece having, in combination, a head reciprocable parallel to the axes of said bores, a plurality of expandable and contractible rotary honing tools on said head for operating simultaneously on said bores, individual power actuators selectively operable to expand and contract the respective honing tools, means for advancing said head to enter said tools into said bores and then to recede the head and tools back and forth during rotation thereof, means for energizing said actuators to expand the respective tools and maintain the stones thereof pressed against the bore walls, individual sizing devices associated with the respective tools and each operable to sense the attainment of a predetermined size of the associated work bore during honing thereof, means controlled by the sizing devices of the first said tools to complete its bore to energize the associated actuator and relieve the expanding pressure on the hone, the second tool continuing to hone its bore, mechanism responsive to the detection of proper size of the second bore to relieve the expanding pressure against the bore wall and expand both of said tools against the bore walls to continue the honing of all of the bores simultaneously, and means operable after a measured amount of simultaneous honing of all of said bores to control said actuators and collapse all of said tools.

2. A machine for honing a plurality of parallel bores in a workpiece having, in combination, a head reciprocable parallel to the axes of said bores, expandable and contractible rotary honing tools on said head for operating simultaneously on said bores, individual power actuators selectively operable to expand and contract the respective honing tools, mechanism for actuating said head and controlling said actuators to advance said tools into the bores, expand the tools against the bore walls under heavy pressure and recede the expanded tools to produce primary honing of the bores, devices individually operable to terminate the primary honing by each tool as its bore comes up to size, means operable automatically as an incident to completion of the primary honing by the last tool to finish its bore to initiate collapse of such tool and to cause reexpansion of all of the tools against the bore walls but under reduced pressure whereby to effect supplemental honing of all of the bores simultaneously in the continued reciprocation of said head and rotation of the tools, timing means activated as an incident to said reexpansion of said tools, and means operable after the lapse of an interval measured by said timing means to terminate the supplemental honing of all of the tools.

3. A machine for honing a plurality of parallel bores in a workpiece having, in combination, a head reciprocable parallel to the axes of said bores, a plurality of expandable and contractible rotary honing tools on said head for operating simultaneously on said bores, individual power actuators selectively operable to expand and contract the respective honing tools, mechanism for actuating said head and controlling said actuators to advance said tools into the bores, expand the tools against the bore walls under heavy pressure and recede the expanded tools to produce primary honing of the bores, devices individually operable to terminate the primary honing by each tool as its bore comes up to size, means operable automatically as an incident to completion of the primary honing by the last tool to finish its bore to initiate collapse of such tool and to cause reexpansion of all of the tools against the bore walls but under reduced pressure whereby to effect supplemental honing of all of the bores simultaneously, a timer common to all of said tools activated as an incident to said reexpansion of said tools, and means operable after the lapse of an interval measured by said timer to terminate the supplemental honing by all of the tools.

4. A machine for honing at least two parallel bores in a workpiece having, in combination, a head reciprocable parallel to the axes of said bores, expandable and contractible rotary honing tools on said head for operating simultaneously on said bores, individual power actuators selectively operable to expand and contract the respective honing tools, mechanism for actuating said head and controlling said actuators to advance said tools into the bores, expand the tools against the bore walls under heavy pressure and recede the expanded tools to produce primary honing of the bores, devices individually operable to terminate the primary honing by each tool as its bore comes up to size, means operable automatically as an incident to completion of the primary honing by the last tool to finish its bore to initiate collapse of such tool and to cause reexpansion of all of the tools against the bore walls but under reduced pressure whereby to effect supplemental honing of all of the bores simultaneously, a timer common to all of said tools activated as an incident to said reexpansion of said tools, and means operable after the lapse of an interval measured by said timer to terminate the supplemental honing by all of the tools.
tract the respective honing tools, means for advancing said
head to enter said tools into said bores and then to recip-
rocate the head and tools back and forth during rotation
thereof, means for energizing said actuators to expand the
respective tools and maintain the stones thereof pressed
against the bore walls, individual sizing devices associ-
ated with the respective tools and each operable to sense
the attainment of a predetermined size of the associated
work bore during honing thereof, means controlled by
the sizing devices of the first of said tools to complete its
bore to energize the associated actuator and relieve the
expanding pressure on the hone, the second tool contin-
ing to hone its bore, mechanism responsive to the detec-
tion to proper size of the second bore to relieve the ex-
anding pressure against the bore wall and expand both
of said tools against the bore walls to continue the hon-
ing of all of the bores simultaneously, means controlling
said actuators and operable to prevent reexpansion of
either of said tools until after at least partial collapse
thereof, and means operable after a measured amount of
said simultaneous honing of all of said bores to control
said actuators and collapse all of said tools.

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