United States Patent [19]

Bovensiepen et al.

[11] **3,848,365**

[45] **Nov. 19, 1974**

[54] **LAPPING OR HONING MACHINE**

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[22] Filed: **Jan. 16, 1973**

[21] Appl. No.: **324,048**

[30] **Foreign Application Priority Data**

Feb. 1, 1972 Germany..... 2204581

[52] **U.S. Cl.**..... **51/111 R,** 51/165.9, 51/281 R, 51/283

[51] **Int. Cl.**..... **B24b 7/00,** B24b 49/08, B24b 1/00

[58] **Field of Search**... 51/109, 111 R, 165 R, 165.9, 51/281 R, 283

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Attorney, Agent, or Firm—Burgess, Dinklage & Sprung

[57] **ABSTRACT**

An improvement in a lapping or honing machine equipped with a pressure unit on the lap or hone and a control unit by which the power input to the pressure unit is adjustable which improvement comprises means to steplessly increase the pressure of the lap or hone on the workpiece from a pre-determined value toward a maximum value; preferably containing means for holding the pressure constant at the elevated pressure for a pre-determined time and to thereafter diminish the pressure of the lap or hone on the workpiece to a pre-determined lower value. Means for adjusting the pressure are disclosed employing a particular valve in a hydraulic system which hydraulic system gradually effects an increase in pressure of the lap or hone upon the workpiece, maintains the pressure at an elevated value for a pre-determined period of time and thereafter gradually decreases the pressure thereon to a pre-determined lower level. There is also disclosed suitable other means for accomplishing the stepless increase of the pressure of the lap or hone on the workpiece.

13 Claims, 7 Drawing Figures

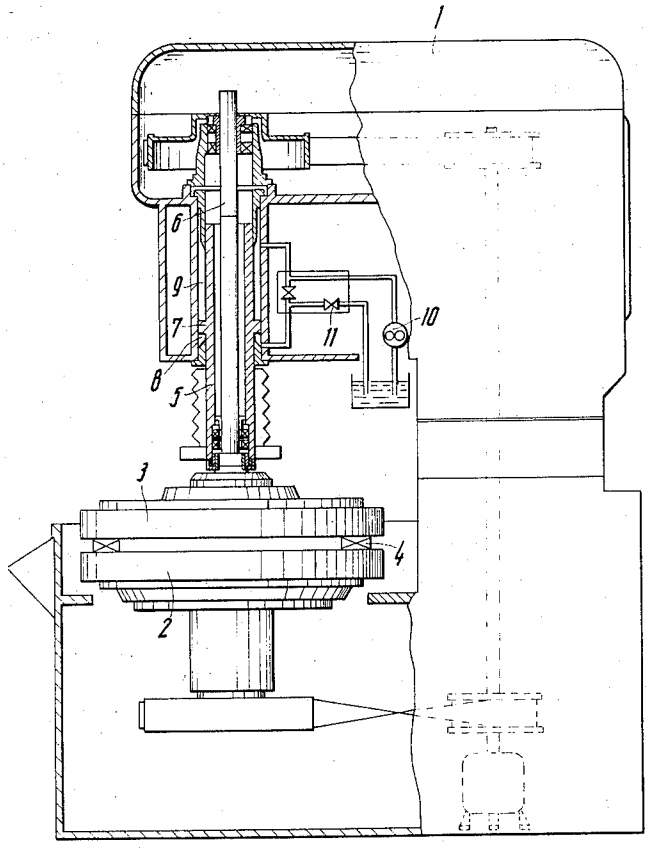
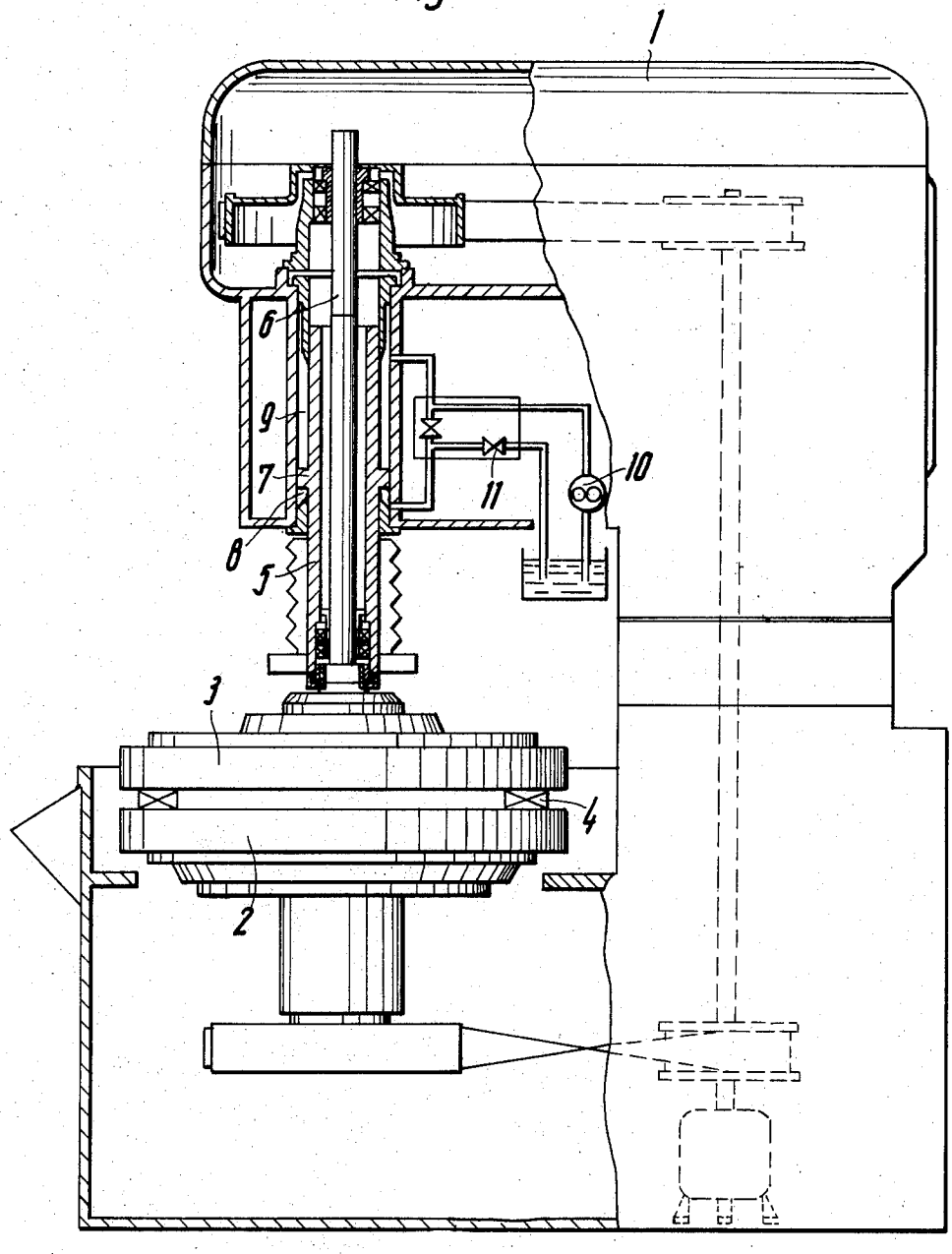


Fig.1



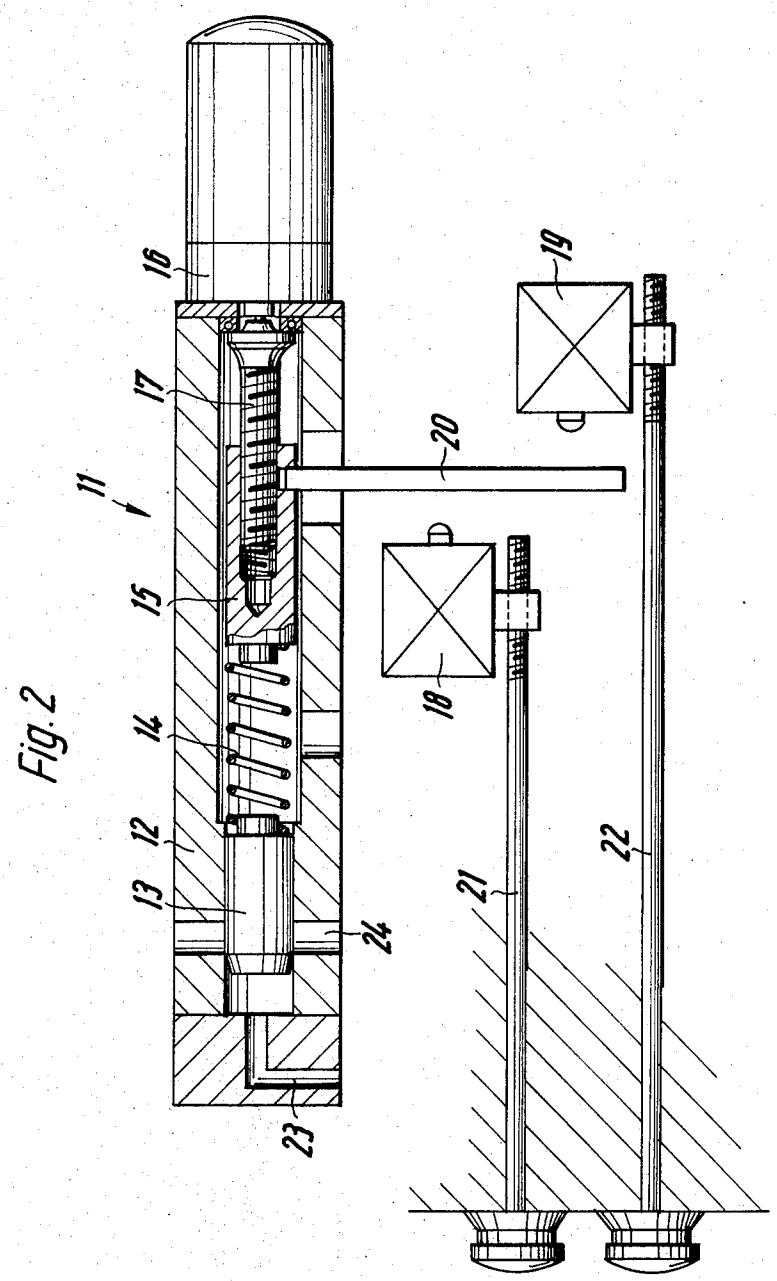
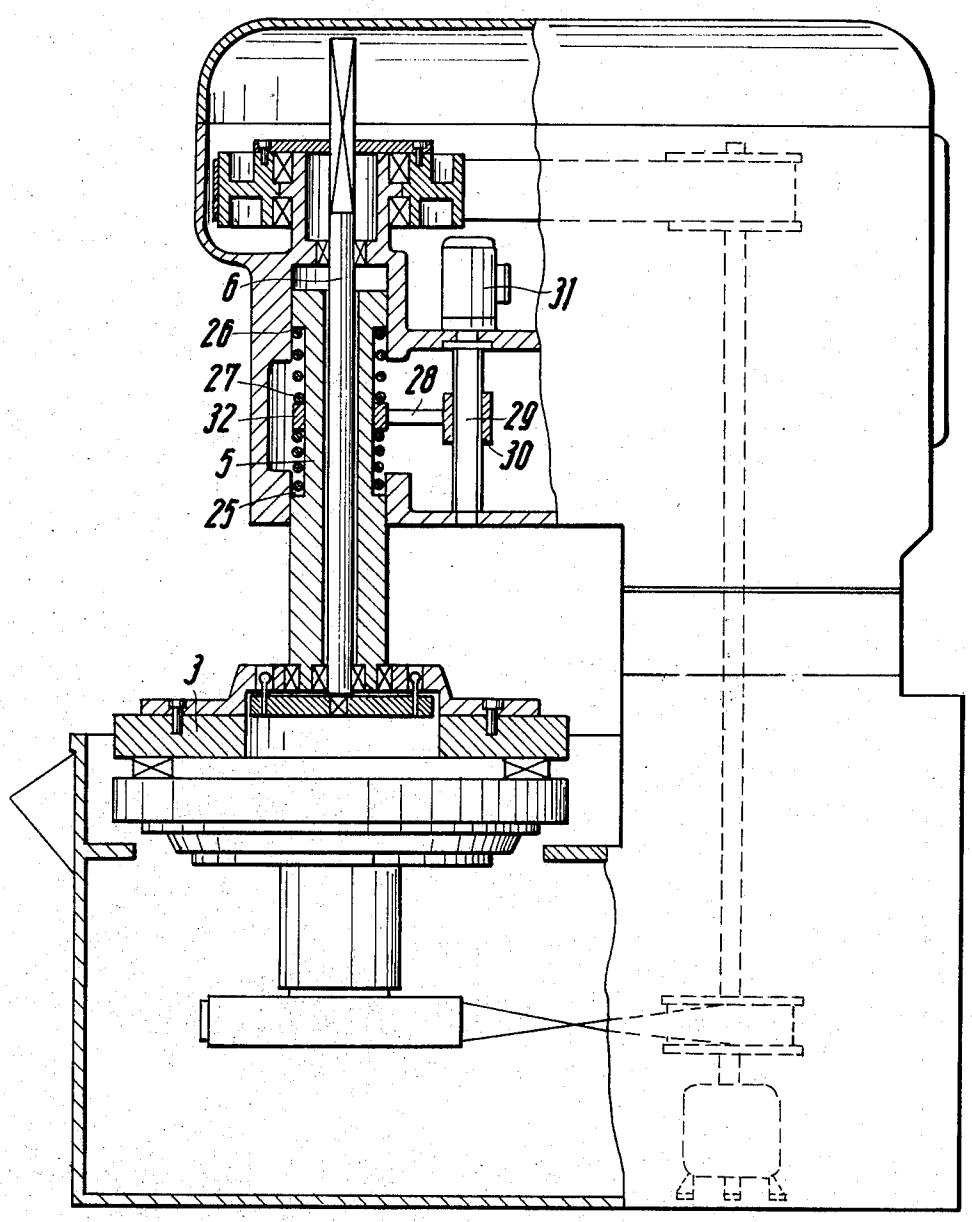


Fig. 2

Fig. 3



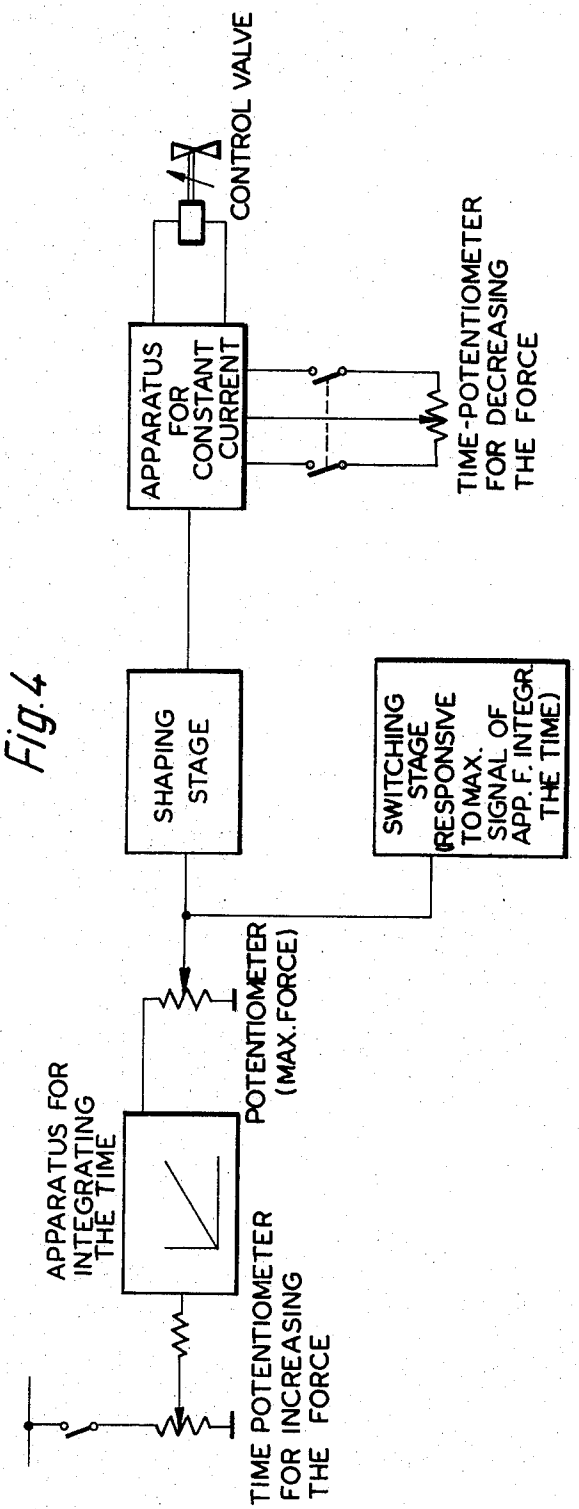

CONTROL VALVE
APPARATUS FOR CONSTANT CURRENT
TIME-POTENTIOMETER FOR DECREASING THE FORCE
SHAPING STAGE
SWITCHING STAGE RESPONSIVE TO MAX. SIGNAL OF APP. F. INTEGR THE TIME)
POTENTIOMETER (MAX. FORCE)
APPARATUS FOR INTEGRATING THE TIME
TIME POTENTIOMETER FOR INCREASING THE FORCE

Fig. 4

Fig. 5

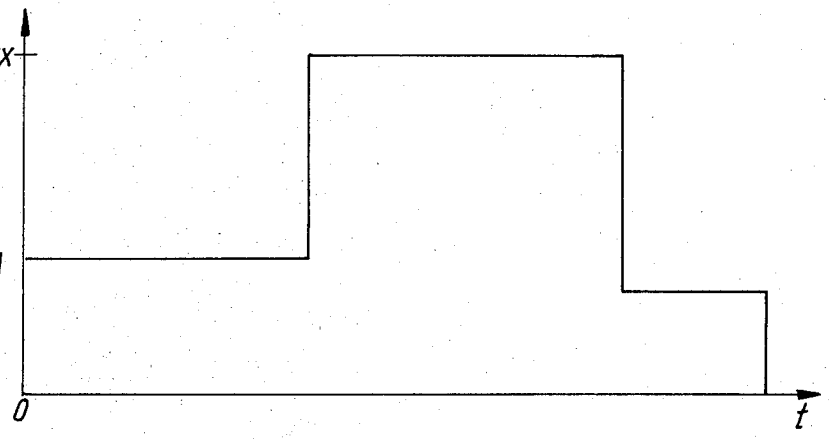


Fig. 6

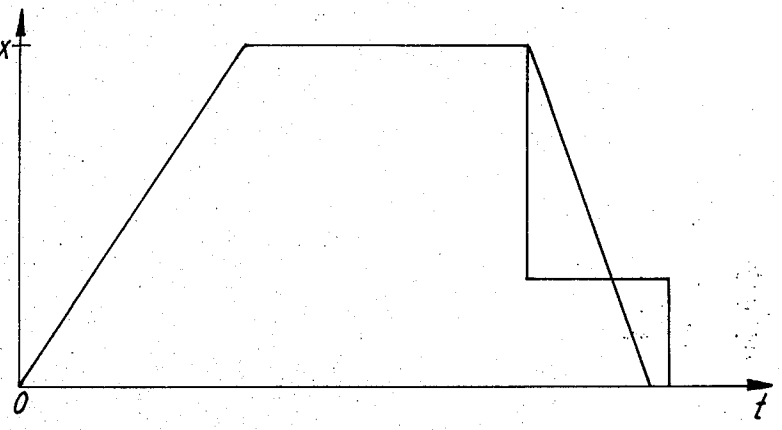
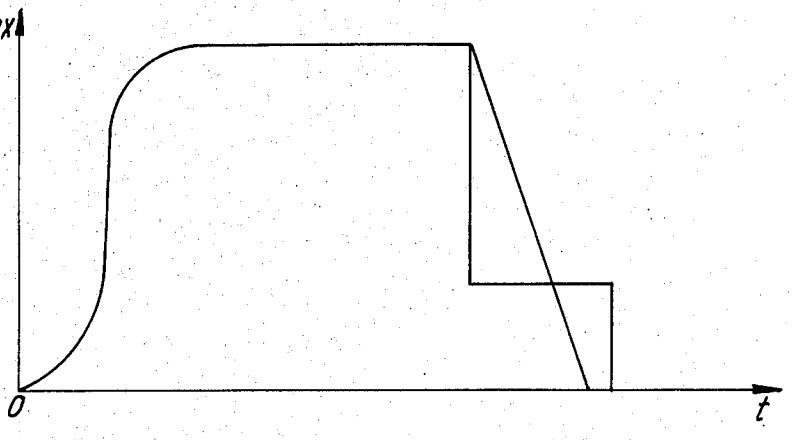


Fig. 7



LAPPING OR HONING MACHINE

BACKGROUND OF THE INVENTION FIELD OF THE INVENTION

The invention relates to a lapping or honing machine with a pressure unit acting on the lap or hone and with a control unit by which the power input to the pressure unit is adjustable.

DISCLOSURE OF THE PRIOR ART

In known lapping or honing machines the pressure unit consists of a cylinder piston unit to which hydraulic fluid can be delivered at both ends. The cylinder piston unit is connected to a hydraulic fluid source through a valve for adjusting the specific contact pressure of the lap or hone to the workpiece surface. The valve permits only a step-wise adjustment of the pressure. This step-wise pressure adjustment has proven to be disadvantageous, because in the machining of workpieces on lapping or honing machines there is the problem that, at the beginning of the operation, only a portion of the surface is engaged by the lap or hone, because the thickness of the workpieces varies. If from the beginning of the lapping or honing process the maximum power is delivered to the pressure unit, which is determined on the basis of the entire workpiece area to be worked during the main operation at optimum specific working pressure, there is the danger that this pressure will be too great and will exceed the optimum specific working pressure on account of the portion of the workpiece surface that is engaged at the beginning of the operation. The excessively high specific working pressure causes the film of lapping agent to break down, so that the lap or hone is attacked and eroded by the workpieces. Precision lapping or honing is then no longer possible.

To remedy this disadvantage it has been proposed that the pressure unit of the lapping or honing machine be operated in two stages, first at a low pressure and then at the maximum pressure corresponding to the optimum specific working pressure. Although this has substantially eliminated the disadvantage of lap or hone erosion, this two-stage raising of the pressure lengthens the time of the operation considerably, because the low pressure has had to be maintained for a relatively long period, so that the lapping or honing machine does not always operate at the optimum specific working pressure. Furthermore, however, the accuracy of shape of the workpieces is not always the best.

SUMMARY OF THE INVENTION

Broadly, this invention contemplates an improvement in a lapping or honing machine equipped with a pressure unit on the lap or hone and a control unit by which the power input to the pressure unit is adjustable which improvement comprises means to steplessly increase the pressure of the lap or hone on the workpiece from a pre-determined value toward a maximum value. Preferably, means are provided to hold the pressure constant at the elevated pressure for a period of time. An especially desirable embodiment of the present invention further comprises means to diminish the pressure from the pre-determined elevated pressure value to a pre-determined lower value.

An especially desirable embodiment of the present invention comprises an electric motor in association with the pressure unit which electric motor is adaptable to gradually increase the pressure of the lap or hone by increasing the pressure in the pressure unit.

An especially desirable embodiment of the present invention is one wherein the aforementioned pressure unit comprises a tubular member containing a driven shaft rotatably attached to the lap or hone which bears on the workpiece. It is this lap or hone which has its pressure increased or decreased pursuant to the invention. The tubular member is housed within a cylinder and the tubular member has an exterior ring member extending or protruding from the surface thereof to the cylinder. This defines at least one ring shaped zone to contain hydraulic fluid. As will be seen from the description below, preferably this ring shaped extension is positioned from the tubular member such as to define at least two generally ring shaped chambers. The zones or chambers are provided with a hydraulic fluid inlet in fluid communication therewith and with a source of hydraulic fluid, e.g., a hydraulic fluid reservoir. Disposed between the ring shaped zones or chambers and the hydraulic fluid reservoir is a valve which has a hydraulic fluid entrance and a hydraulic egress in fluid communication with one another through a channel. The channel contains a regulatable bore movable therein in response to an electrical system. The electrical system comprises a pre-determined program whereby the bore, initially, increasingly covers the hydraulic fluid egress and permits fluid flow through the inlet only so as to increase the pressure in the ring shaped zone and thus to move the tubular member and, in turn, the driven member attached to the lap or hone with increasing pressure on the workpiece. The bore moves until such time as it completely covers the hydraulic fluid egress. Such is recorded in the electric motor due to the presence of an arm or extension of the bore which triggers a limit switch. Thereafter, the pressure is maintained at its maximum value for a predetermined period of time. The bore is caused by the electric motor to retreat in the channel whereby to increasingly allow the escape of more hydraulic fluid through the egress until all of the hydraulic fluid has escaped and the pressure is reduced to a pre-determined desirably low value.

It should be understood that the bore can comprise a plurality of mechanical members such as a drivable spindle connected to the electric motor which can bear upon a spring such as a coil spring which, in turn, will bear upon the tip of the bore which covers and uncovers the hydraulic fluid egress.

Another desirable embodiment of the invention which gradually increases in a stepless manner the pressure of the lap or hone on the workpiece comprises a driven means connected to the pressure unit of the lapping or honing machine which driven means is in association with a preprogrammed electrical motor operative to constantly move the pressure unit to increase the pressure of the lap or hone upon the workpiece, to hold the same at a predetermined maximum pressure for a predetermined period of time and, thereafter, to gradually reduce the pressure to a predetermined final value. This embodiment, as will be seen from the discussion below, comprises a driven means such as a spindle fixed to an arm which bears against a pair of springs on either side thereof, each of which springs bears against a housing member containing the drive for said hone or lap. One spring will bear against a pro-

trusion of the housing member relatively close to the hone itself, i.e., downstream of the arm. The other spring will be positioned against a protrusion of the housing member remote from the arm whereby movement in that direction relieves the lap or hone from the workpiece. The pressure is adjusted due to the movement of the spindle means which moves the arm to compress the spring to urge the housing toward or away from the workpiece. Initially, of course, the housing is urged toward the workpiece. Thereafter, the motor will reverse itself, the spindle will turn in opposite direction, the arm will move upward bearing against the remote spring in turn bearing against a protrusion of the housing member whereby to move the same away from the workpiece.

Thus, the invention is addressed to the problem of a lapping or honing machine by which workpieces having dimensional variations in their thickness can be worked more quickly and with better accuracy of shape in comparison with the lapping and honing machine of the prior art.

This problem is solved in accordance with the invention, in a lapping or honing machine of the initially described kind, in that the control unit for the stepless adjustment of the power input to the pressure unit is controlled by a given program in which the power increases from an initial value, e.g., zero, to a maximum value, then is held at this maximum value for a predetermined length of time, and finally diminishes to an end value, e.g., zero.

With a lapping or honing machine of this type, shorter operating time and greater accuracy of shape are achieved than in machines of the prior art, because the power is not increased abruptly but continuously as the palling or honing surface area gradually increases, so that the machine is operated substantially at the optimum specific working pressure. The decrease of power from the maximum to an end value such as zero additionally contributes to qualify. The reduction of power can be performed in steps or continuously, according to requirements.

Satisfactory results are achieved with a program in which the increase of power takes place merely in a linear manner. Optimum results can be achieved if, according to a further embodiment of the invention, the control unit is set up for the stepless control of the power from the initial value to the maximum value in such a manner that the power increases according to an S curve. This embodiment of the invention is based on the idea that the tolerance variations of the workpieces being machined follow the Gauss distribution curve. If the workpieces are to be lapped or honed at optimum specific working pressure during the entire operation, the power increase in relation to time, i.e., power increase rate, must be greatest in the area in which the greatest frequency of the dimension of greatest deviation from the desired dimension of the workpieces lies. Since only a small number of workpieces have a great tolerance deviation, the power increase in relation to time may take place slowly at the beginning of tht total working time and in the transition to the main working time.

According to an advantageous embodiment of the invention, the pressure unit is a cylinder piston unit which can be operated by hydraulic fluid and the control unit is a pressure valve connected to the hydraulic fluid feed line. The pressure valve can easily be controlled according to a further embodiment of the invention when it has a spring-loaded valve body, a drive acting on the spring in accordance with the predetermined program to establish the spring bias which determines the pressure of the hydraulic fluid. Suitable drives, are for example, cams or program-controlled electric motors. To be able in a simple manner to adjust the initial pressure and end pressure on the one side and the maximum pressure on the other, limit switches can be associated with the drive.

For small-size lapping or honing machines an especially suitable pressure unit is one which has a program-controlled electric motor spindle drive in which the part that moves along the spindle acts through a spring on the lap or hone. The controlling of the power in this pressure unit is performed through an electrical control system.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be further explained hereinafter with the aid of a drawing showing embodiments thereof in which:

FIG. **1** is a side elevation partially broken away of a lapping or honing machine with a hydraulically operated pressure unit.

FIG. **2** is a partially diagrammatic longitudinal cross section of a valve for the adjustment of the pressure of the hydraulic pressure unit of the lapping or honing machine of FIG. **1.**

FIG. **3** is a lapping or honing machine with an electric motor spindle drive for the pressure unit, in a side view partially broken away.

FIG. **4** is a block circuit diagram of an electrical control system.

FIG. **5** is a diagram of time versus power in the operation of a lapping or honing machine of the prior art.

FIG. **6** is a diagram of time versus power in the operation of the lapping or honing machine of the invention, and

FIG. **7** is another program of time versus power in the operation of the lapping or honing machine of the invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

The lapping or honing machines represented in FIGS. **1** and **3** are of the same construction except for the pressure unit. They consist of a column **1,** a lower, driven lap or hone **2,** and an upper, driven lap or hone **3.** Between the two laps or hones **2, 3,** are located the workpieces **4** which are to be lapped or honed. The upper lap or hone **3** is held by a tubular member **5** to whose bottom end it is rotatably mounted. The drive spindle **6** passes through the tubular member **5.**

In the lapping or honing machine of FIG. **1,** the tubular member **5** is constructed in the form of a cylinder piston system that can be fed with hydraulic fluid from both ends, which represents the pressure unit. An exterior piston ring **7** of this cylinder piston system divides the cylinder casing into a lower and upper cylinder chamber **8, 9** respectively. The lower and upper cylinder chambers are supplied with hydraulic fluid from a hydraulic fluid source **10.** The pressure in one cylinder chamber, the lower cylinder chamber **8** in this embodiment, can be varied according to the predetermined program through valve **11,** which serves as a control unit for the stepless adjustment of the power input to the pressure unit. The feeding of hydraulic fluid to both

ends of the cylinder piston unit enables the power to be varied from a zero initial value to a maximum value and vice versa according to any desired curve. The variation can also be brought about through pressure control in the upper cylinder chamber.

An embodiment of a valve **11** is represented in FIG. **2.** In a valve casing **12** a valve body **13** is engaged by a spring **14** which in turn bears against a movable member **15** of a spindle **17** driven by a direct-current motor **16.** Two limit switches **18, 19,** are associated with the movable member **15.** The limit switches cooperate with a projection **20** of the movable member **15.** The limit switch **18** for setting the maximum pressure and the limit switch **19** for setting the initial pressure and end pressure may be varied as to their position in relation to projection **20** by means of spindles **21** and **22.** The valve **11** has its input **23** connected to the upper cylinder chamber **9,** while its output **24** leads back to the reservoir of the hydraulic fluid source **10.** Valve **11** operates as a throttle valve. The desired pressure in cylinder chamber **9** is adjusted through the bias of spring **14.** The spring bias is adjusted by moving the movable member **15** by means of the spindle **17** of motor **16.** Motor **16** is turned on and off and its speed is controlled in accordance with the given pressure.

Instead of the movable member **15** with the spindle **17,** the motor **16** and the limit switches **18** and **19,** a cam bearing the given program on its periphery can also engage the spring **14** in the most simple embodiment. Operation of the pressure increase steplessly by used of the valve body **13** can also be effected electromagnetically. An electrical control system suitable therefor is represented in FIG. **4.** A potentiometer, for example, serves to predetermine the steepness of the flank of the curve representing the increase of the power in relation to time from zero to maximum power. This predetermined time value is processed in the time circuit. At the potentiometer connected to the output of the latter the upper and lower pressure limits can be preset. In a succeeding apparatus the actual curve can be predetermined. On the basis of the curve supplied by this apparatus an apparatus feeding a solenoid is controlled, which automatically compensates voltage fluctuations. The solenoid acts directly on the valve body **13.**

The pressure unit of FIG. **3,** which is especially suited for lapping or honing machines of smaller types has a spindle drive as its pressure unit. On the tubular member **5** there are mounted, between a lower and upper shoulder **25, 26,** two helical springs **27** which are separated by a ring **32.** The ring **32** is engaged by an arm **28** of a nut **30** movable on a threaded spindle **29.** The spindle **29** is rotatably mounted in column **1** of the lapping or honing machine. The spindle **29** is driven by an electric motor **31** which is controlled in accordance with the given program.

In FIGS. **6** and **7** the working diagrams of the lapping or honing machine of the invention are compared with the working diagram of a known lapping or hoining machine. As initially explained, the increasing of the pressure, or of the power of the pressure unit, is performed in known lapping machine in a step-wise manner. As represented in FIG. **5,** the operation begins with a power K_A. This power is too great at the beginning of the operation, so that the optimum specific working pressure is exceeded and the danger exists that some of the workpieces may erode the lap. At the end of the lapping operation at power K_A, however, the power is too low to achieve an optimum working pressure. Here, of course, there is no longer any danger of erosion, but at the end of the operation at power K_A the machine is no longer being operated under optimum conditions. Immediately after the power is raised from K_A to K_{max}, the same problem exists as at the beginning of the operation. The power K_{max} is too great for an optimum specific working pressure, so that the lap surface is eroded. To keep the danger of erosion as low as possible, it is necessary to operate the machine as long as possible at the reduced power K_A. This results in a prolongation of the total lapping or honing operation. Since on the other hand it is desired to get by with the shortest possible operating time, the power is increased to K_{max} just at a time when the film of lapping agent can break down and erosion can occur at the workpiece surface or the lap surface. This results in a less than optimum accuracy of shape in the end product.

A greater accuracy of shape combined with shorter operating time can be achieved with the lapping or hoing machine in accordance with the invention, in which the power is increased steplessly to the maximum value K_{max}. In the case of a linear power increase as in FIG. **6,** the operation is performed with only approximately the optimum specific pressure. This is especially true with regard to the power increase in the middle range. Optimum results are obtained, however, when the program increases the power according to an S-curve from the value zero to the value K_{max}, as represented in FIG. **7.** This curve for the power increase is determined on the basis of the Gaussian bell-shaped curve for dimension distributions. As it will be seen from a comparison of FIGS. **6** and **7** with FIG. **5,** the overall working time is shortened in the lapping or honing machine of the invention on the basis of the continuous increasing of the power to the maximum value for the optimum specific working pressure. In addition to the shorter operating time the invention results in a better accuracy of shape in the workpieces.

What is claimed is:

1. In a lapping or honing machine equipped with a pressure unit on a driven lap or hone to apply lapping or honing pressure to a workpiece and a control unit by which power input to the pressure unit is adjustable, the improvement which comprises means to steplessly increase the pressure of said driven lap or hone on the workpiece from a predetermined value toward a maximum value.

2. An improvement according to claim **1** including means to hold the pressure constant at an elevated pressure for a predetermined period of time.

3. An improvement according to claim **2** including means to automatically diminish the pressure on the driven lap or hone on the workpiece to a predetermined lower value after the pressure has been held constant at an elevated pressure for a predetermined period of time.

4. An improvement according to claim **1** wherein said control unit is set up for the stepless adjustment of the power from the initial value to a maximum predetermined value in such a manner that the power increases according to an S curve.

5. An improvement according to claim **1** wherein said means to steplessly increase the pressure of said driven lap or hone against the workpiece comprises an electric motor and an hydraulic system, said hydraulic

system connected mechanically to said electric motor and being responsive to said electric motor, said hydraulic system connected to said pressure unit.

6. An improvement according to claim **1** wherein said pressure unit comprises a tubular member containing a driven shaft rotatably attached to said lap or hone, a cylinder, said tubular member housed within said cylinder, said tubular member having an exterior ring member extending from the surface of said tubular member to said cylinder, an hydraulic fluid inlet in free communication with the so-formed ring shaped region over said exterior ring, a reservoir containing hydraulic fluid, said hydraulic fluid inlet connected to said reservoir of hydraulic fluid by way of a valve, said valve comprising an hydraulic fluid entrance and an hydraulic egress, a channel, said hydraulic fluid entrance and hydraulic egress in fluid communication with one another through said channel, said channel containing a regulatable bore movable in said channel, an electrical system for regulating said bore in said channel.

7. An improvement according to claim **6** wherein said electrical system comprises an electrical motor and a pair of limit switches, said bore has a lateral extension which is movable upon movement of said bore to engage at least one of said limit switches whereby when said electrical system commences operation the end of said bore increasingly overlies said hydraulic egress permitting increasingly more hydraulic fluid to pass into said hydraulic fluid inlet whereby to constantly increase the pressure of said hone or lap on said workpiece when a predetermined period of time has elapsed thereafter, as determined by said extension being in contact with a limit switch, said bore is caused to increasingly open said egress permitting return of said hydraulic fluid to said reservoir thereby effecting a constant decrease in pressure.

8. An improvement according to claim **7** wherein said exterior ring defines two ring-shaped zones in said cylinder both of which are connected to an hydraulic fluid inlet and each hydraulic fluid inlet is in fluid communication with said hydraulic entrance of said valve.

9. An improvement according to claim **1** wherein said pressure unit is connected to a driven means of a pre-programmed electrical motor operative to constantly move said pressure unit to increase the pressure of said lap or hone on said workpiece, to hold the same at a predetermined maximum pressure for a predetermined period of time thereafter to gradually reduce the pressure.

10. An improvement according to claim **9** wherein said driven means comprises a spindle affixed to an arm which bears against a pair of springs on either side thereof, said apparatus further comprises a housing member on which said pair of springs bear, a driven shaft housed in said housing member, said driven shaft connected to said hone or lap whereby movement of said spindle moves said arm to compress a spring to urge said housing toward or away from the workpiece.

11. An improvement according to claim **1** wherein said means to steplessly increase the pressure comprises a contoured cam whose periphery controls the gradual increase in pressure, the time at which the lap or hone is at a maximum predetermined pressure and whose periphery controls decrease in the pressure to a predetermined lower value, said cam connected to a driving means and bearing on said pressure unit.

12. A process for lapping or honing at least one workpiece which comprises moving the workpiece along a circular path between a lapping or honing disk such that it is concentrical to said lapping or honing disk, pressing the lapping or honing disk against the workpiece during the lapping or honing process with a force which is increased to such extent from an initial starting value to a maximum value while considering the increasing working area of the workpieces during the lapping or honing process, the specific work pressure applied against the workpiece being maintained constant and thereafter, after the force is maintained constant for a predetermined period of time at the maximum work pressure, diminishing the work pressure to a final value.

13. A lapping or honing machine according to claim **1** additionally comprising including means for moving a workpiece in a concentrical circular path to said driven lap or hone.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,848,365 Dated November 19, 1974

Inventor(s) Hans-Friedrich Bovensiepen et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Under Assignee

"Walters" should read "Wolters"

Signed and sealed this 13th day of May 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks