

Sept 10, 1957

A. F. HASTY ET AL  
AUTOMATIC HONING MACHINE

2,805,521

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2 Sheets-Sheet 1

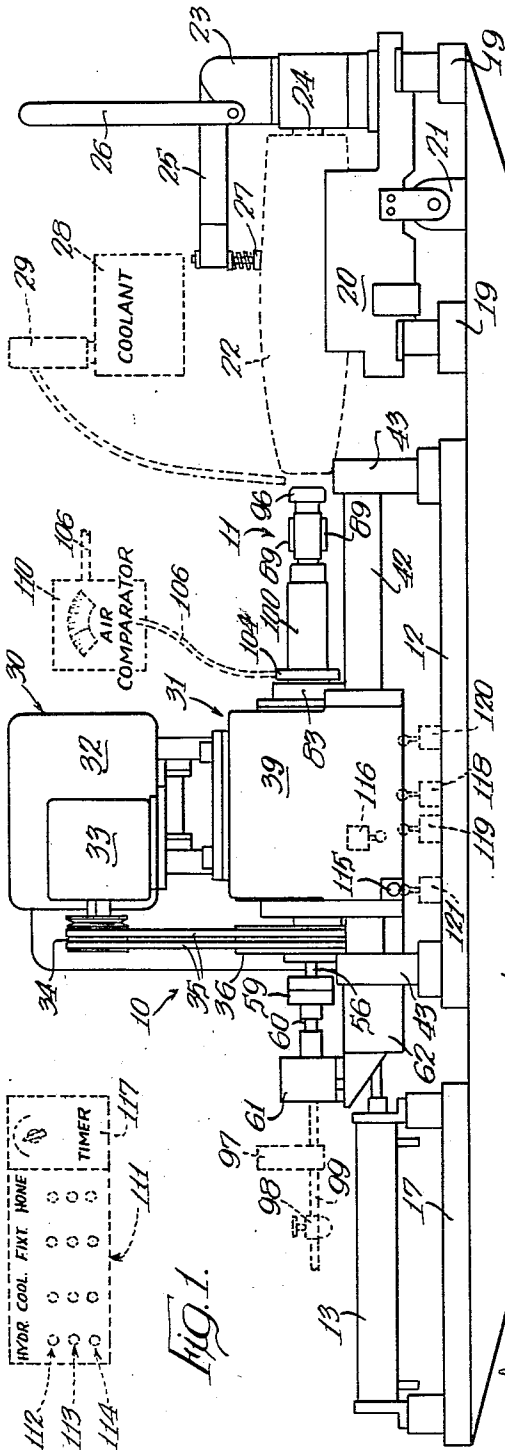


Fig. 1.

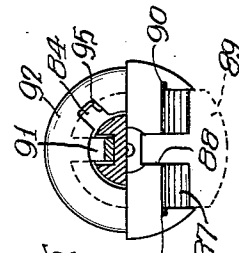


Fig. 5.

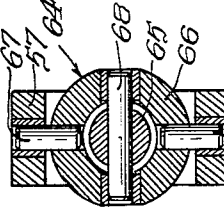


Fig. 3.

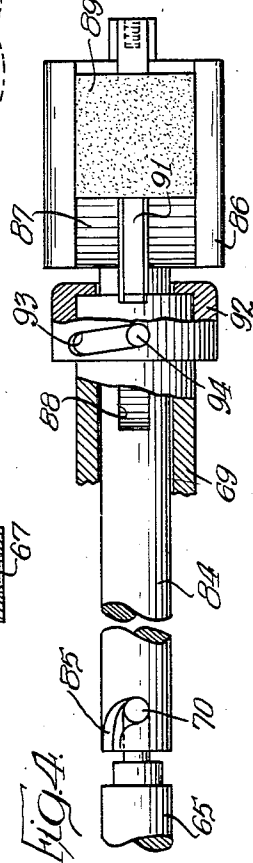


Fig. 4.

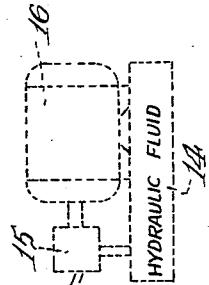


Fig. 2.

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1

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## AUTOMATIC HONING MACHINE

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14 Claims. (Cl. 51—34)

The present invention relates to honing apparatus, and particularly, to an improved honing machine facilitating the automatic and accurate honing of articles of manufacture at a high production rate.

Honing is a well known method of working articles of manufacture, particularly the bores and cavities in metallic articles, to highly accurate finished dimensions and to an exceedingly smooth surface finish. Because of the finiteness of finished dimension to be obtained, honing is a quite delicate operation and every precaution must be taken to insure accuracy. Accordingly, honing is not immediately suited to methods of mass production. However, a number of machines have been developed and marketed which bring honing to practical commercial use for modern standards.

It is, broadly, an object of the present invention to improve upon known honing machines to render the same even more widely and effectively suited for mass production manufacture and to afford an even greater degree of accuracy for honing operations.

In particular, three principal problems have been encountered in production with known honing machines, all of which comprise obstacles to development of a fully automatic machine and at least two of which are substantial deterrents to attainment of the degree of accuracy desired, these three unsolved problems thus necessitating operation of known honing machines at slower production rates than the machines otherwise would be capable of. The first problem relates to the expansive force of the honing stones, the second to the alignment of the honing tool or mandrel and the work piece, and the third to the gauging of the work piece after honing.

It is an object of the present invention to provide an improved honing machine overcoming the three problems noted and accommodating fully automatic operation of the machine at the fastest rate possible for a given honing operation.

Considering the first problem stated above, it is to be observed that honing tools conventionally comprise a rotatable mandrel carrying a plurality of honing stones which are movable radially with respect to the mandrel into and out of engagement with the walls of the bore or the like to be honed. The stones are normally retracted to accommodate entry thereof into a bore, and after entry, while the mandrel is rotated within the bore, the stones are biased outwardly into engagement with the walls of the bore to perform work upon the same. Heretofore, spring means have been employed to bias the stones outwardly, the spring means affording the advantage of resiliently biasing the stones into engagement with the work, rather than positively forcing the same into the work. However, spring means suffers the decided disadvantage that the force applied to the stones and thus to the work cannot be of uniform pressure for all settings or degrees of compression of the spring means, which creates serious problems with respect to calibration and adjustment of the machine, since

2

it is essential that only a given resilient force be exerted for a given interval.

An object of the present invention is to overcome the above stated problems and difficulties inherent in known honing machines by providing means for exerting a constant, even, readily adjusted, resilient force on the honing stones during honing. Specifically, it is an object of the invention to provide an improved honing machine including fluid pressure operated means exerting a constant, uniform biasing force on the stones during honing.

With respect to the second problem above stated, it is exceedingly difficult in mass production to align an article of manufacture to be honed perfectly with the honing tool. Yet, the alignment must be perfect if the honing is to be accurate. Misalignment in production is usually the result of slightly off-center positioning of the bore in an article, or of an inability to locate the bore axially in alignment with the honing tool. In almost all cases, the degree of misalignment is relatively small in terms of abstractly considered physical dimensions, but when considered in the light of the exceedingly small change in dimension to be effected by the honing tool, misalignment is a very substantial problem.

Another object of the present invention is to overcome the alignment problem by provision of self-aligning means for honing machines which accommodates automatic alignment of the honing tool axially of the bore to be honed even if the axis of the bore is laterally offset and/or angularly related to the normal axis of rotation of the honing tool. In particular, it is an object of the invention to provide an improved honing machine including mandrel supporting means accommodating lateral and/or angular offset of the mandrel, said means being self-aligning and normally supporting the mandrel for rotation about a given axis, said means accommodating movement of the mandrel upon insertion and rotation of the mandrel in a bore to permit the mandrel to align itself axially of the bore due to engagement of the honing stones with the wall of the bore.

In all honing operations, it is necessary to gauge the honed bore to insure that the same is of proper size and that the honing operation has been properly carried out. Pneumatic plug gauges have come into wide use for this purpose and are highly practical. However, at present, it is necessary to remove the honing tool from the honed bore, and separately to insert the plug gauge. The gauge may be inserted into the honed bore manually or by separate machinery, or the gauge may be stationary and the work piece slipped onto the gauge. In any case, the work piece or article of manufacture must be removed from the honing machine and/or its jig, and if the bore is undersize, the work piece must be re-set-up on the honing machine, with attendant alignment problems, to effect a more thorough honing, all of which appreciably slows production, as will be apparent.

It is also an object of the invention to overcome this problem by provision of pneumatic plug gauge means in combination with a honing tool to accommodate gauging of the honed bore directly on the honing machine and as an automatic, rapidly performed step in the operation of the machine, without requiring any movement whatever of the work piece or article of manufacture. More specifically, it is an object of the invention to provide an improved honing machine including a rotatable mandrel having honing stones at the outer end thereof, and a pneumatic plug gauge mounted concentrically about the shank of said mandrel immediately adjacent said stones, said gauge being insertable in the honed bore to gauge the same upon moving said stones and said mandrel deeper into the bore.

A further object of the present invention is the provi-

sion of a single improved honing machine incorporating all of the above objectively stated features of the invention.

A still further object of the invention is the provision of an improved honing machine that automatically carries out a complete honing operation and that is adapted to fully automatic control and performance of all facets of honing procedure in the mass production of articles of manufacture.

Other objects and advantages of the present invention will become apparent in the following detailed description of a preferred embodiment of the invention.

Now, in order to acquaint those skilled in the art with the manner of making and using the honing machine of our present invention, we shall describe, in connection with the accompanying drawings, a preferred embodiment of our machine and a preferred manner of making the same.

In the drawings:

Figure 1 is a side elevation of the honing machine of the invention, the view showing the operating structure of the machine per se in solid lines and the control panel, control switches, control valve, hydraulic reservoir and pump, coolant reservoir and pump and air gauge comparator in dotted lines, these latter components being represented in dotted lines since the same, for purposes of clarity, have not been shown in their proper physical location, the view also showing in dotted lines a work piece to be honed;

Figure 2 is a horizontal sectional view, on an enlarged scale, of the honing apparatus shown in solid lines in Figure 1;

Figure 3 is a cross sectional view, on a further enlarged scale, of the means accommodating alignment of the honing tool with a bore to be honed, the view being taken substantially on line 3—3 of Figure 2;

Figure 4 is a fragmentary plan view, partly in section and partly in elevation, of the mandrel assembly, the view being taken substantially on line 4—4 of Figure 2; and

Figure 5 is a vertical sectional view of the mandrel assembly, the view being taken substantially on line 5—5 of Figure 2.

Referring now to the drawings, and particularly to Figure 1, we have indicated the honing apparatus per se of our invention at 10, the apparatus including a rotatable honing tool or mandrel, indicated generally at 11. The apparatus 10 is slidably mounted on a base plate 12 for reciprocatory movement longitudinally of the mandrel 11, a hydraulic motor 13 of the piston type being operatively associated with the apparatus 10 to reciprocate the same. The hydraulic motor 13 is actuated by hydraulic fluid supplied to the motor under pressure from a fluid reservoir 14 through a pump 15, the pump being operated by an electric motor 16. In assembly, the base 12 is preferably individual to the apparatus 10, to constitute the same a complete assembly, as will appear more fully hereinafter.

The piston of the hydraulic motor 13 is preferably connected to the apparatus 10 and the cylinder of the motor is mounted on a separate base plate 17. The base plates 12 and 17 are mounted in aligned spaced relation on a pair of spaced parallel base beams 18, the said members 12, 17 and 18 thus comprising the base of the honing machine of the invention. Mounted on and forming part of the base are a pair of spaced parallel transverse guide rails 19 which are disposed forwardly of and at right angles to the mandrel 11 of the apparatus 10. A carriage 20 is slidably mounted on the guide rails 19 for reciprocatory movement at right angles to the mandrel 11, the carriage preferably being dove-tailed to the rails or having a like connection therewith. The carriage 20 is adapted to be reciprocated by means of a hydraulic motor 21, which is also actuated by fluid from the reservoir 14, the

motor 21 being mounted on the base of the machine between the rails 19 beneath the carriage 20.

The carriage 20 comprises a work piece holding fixture or jig defining at least one and preferably two or more cradles or stations for receiving work pieces. In the preferred embodiment, two cradles are defined, each adapted to receive a work piece 22 having a bore therein to be honed. In Figure 1, the shell portion of an explosive shell is shown as the work piece, the shell having an axial bore therethrough defining a cylindrical cavity or bore portion at the forward end of the shell adapted to receive an arming mechanism, this portion of the bore being required to be very accurately honed for the intimate reception of the mechanism. While reference is made herein to the honing of this specific work piece, it is obvious that the invention is applicable to a wide variety of honing operations. At each cradle or station thereof, the fixture or carriage 20 includes an upstanding arm 23 defining an abutment stop 24 for the work piece and a second arm 25 pivoted to the upper end of the arm 23 and normally extending therefrom toward the mandrel 11 to overlie the work piece. A lever 26 is connected to the arm 25 to pivot the same from a vertical position in alignment with the arm 23 to the horizontal position shown in Figure 1, the pivot connection of the two arms preferably including detent means (not shown) releasably to hold the arm 25 in each of the two positions thereof. At its outer end, the arm 25 includes a spring pressed abutment 27 adapted to engage the upper surface of the work piece 22 to retain the work piece in its cradle. Upon motion of the lever 26, as shown in Figure 1, downwardly to the right, the arm 25 and abutment 27 are moved to release the work piece, whereupon the one work piece may be removed and another inserted in its place. By provision of two stations or cradles, a honed work piece may be removed and an unhoned work piece substituted therefor at one station, manually or by appropriate apparatus known in the art, while the apparatus 10 is honing another work piece at the other station, so that the honing machine is never idle in production. The motor 21 for actuating the carriage or fixture 20 is preferably adjusted or provided with stops (not shown) automatically to locate each of the work piece stations substantially in longitudinal alignment with the honing mandrel 11, so that upon energization of the motor the bore in a work piece is automatically brought substantially into axial alignment with the mandrel, the other station of the fixture then being laterally offset from the mandrel 11 to facilitate changing of work pieces at the other station even while the apparatus 10 is in the process of honing a work piece.

In honing operations, it is customary to afford a liquid coolant for the honing tool and work piece, and the machine of the invention includes conventional means for this purpose comprising a coolant reservoir 28 and a pump 29 for pumping coolant from the reservoir to the mandrel 11. In a complete machine structure, the base beams 18 are normally supported by legs to elevate the honing apparatus 10 and fixture 20 to a convenient working height, in which case the reservoirs 14 and 28 and pumps 15 and 29 are normally positioned beneath the beams and enclosed within a suitable sheet metal housing. For the sake of clarity and to avoid excessive illustration, the complete machine structure has not been shown herein, the pumps and reservoirs being merely represented in dotted lines to indicate that the true physical location, structure and size thereof have not been shown.

The honing apparatus per se of the invention, as indicated at 10, is shown in Figure 1 as including upper and lower portions 30 and 31, respectively, the upper portion 30 being mounted on the lower portion 31 and including an electric motor 32. For purposes of braking the motor 32, to prevent coasting of the operable components of the apparatus upon deenergization of the motor, a plugging switch motor 33 is connected to the shaft of the motor 32 by a belt drive. A pulley 34 is mounted on

5

the shaft of the motor 32, the pulley 34 presenting a plurality of belt surfaces over which a plurality of belts 35 are reaved to establish driving connection between the shaft of the motor 32 and a pulley 36 included in the lower portion 31 of the apparatus. As shown in Figure 2, the pulley 36 is keyed to the outer end of a tubular shaft 37 which is rotatably mounted at its inner end by means of bearings 38 in the housing 39 of the lower portion 31 of the apparatus.

The housing 39 is preferably completely closed and includes at the opposite sides thereof a pair of horizontally aligned tubular portions 40 each receiving and retaining a ball bushing in each end portion thereof and a spacer bushing 41a between the ball bushings. Each bushing assembly slidably receives a longitudinal supporting rod 42 of cylindrical form, the rods 42 being disposed in spaced parallel relation to one another and the base plate 12 and being fixedly supported at the opposite ends thereof by upright supports or stanchions 43 which are fixedly mounted on the base plate 12. Accordingly, the housing 39, and thus the entirety of the portions 30 and 31 of the apparatus 10, are slidably mounted on the stationary rods 42 by the bushings 41 and 41a, whereby the apparatus 10 is mounted for longitudinal reciprocation by means of the hydraulic motor 13. To seal the housing about the rods 42, annular end plates 44 are secured to the opposite ends of the tubular portions 40, and a seal 45 is confined within each end plate sealingly to engage the surface of the respective rod 42. By maintaining the sealed relationship, the housing 39 may serve as a reservoir for lubricating oil to lubricate the moving parts of the apparatus. Preferably, the bushings 41a are exposed and apertured in a conventional manner to accommodate the passage of lubricant to the engaging surfaces of the bushings 41 and 41a and the rods 42. Axially thereof, i. e., midway between the tubular portions 40, the housing 39 is provided with tubular portions 46 and 47 projecting into the interior of the housing from the rear and front walls 48 and 49 thereof, respectively. The tubular portion 46 defines a pair of spaced coaxial bearing mounts 50, within which the outer races of a pair of bearings, the bearings 38 are mounted, the inner races of the bearings being separated by a tubular spacer 51.

The tubular shaft 37 is received within the spacer 51 and the inner races of the bearings 38 and at its inner end includes a radial flange abutting one face of the inner race of the interior bearing, the shaft being secured to the inner races of the bearings 38 and the spacer 51 by means of a C-ring 52 or the like abutting the opposite face of the inner race of the exteriorly located bearing 38. To seal the shaft 37 with respect to the housing 39, an annular end plate 53 is secured to the housing about the shaft, a seal 54 being confined within the end plate sealingly to engage the shaft. The bearings 38 are exposed to the interior of the housing to accommodate lubrication thereof by the lubricant in the housing. At the inner end thereof, the shaft 37 is internally splined slidably but non-rotatably to receive a splined shaft 55 which includes a rearwardly extending elongate stem 56 and which at its forward end is provided with a bifurcated fork portion or clevis 57. The stem 56 of the shaft 55 is secured at its rearward end to the inner race of a bearing 58 which rotatably but non-slidably supports the extension in a two piece connector 59 which is pinned to the forward end of the piston shaft 60 of a pneumatic motor 61. The motor 61 is fixedly supported by frame means 62 extending rearwardly from the housing 39 to be movable longitudinally of the base 12 with the housing and the remainder of the apparatus 10. The motor 61 is a single acting air motor, the piston thereof being movable forwardly by means of air under pressure introduced into the cylinder of the motor and being returned by means of a spring 63. The purpose and function of this motor will be described in greater detail hereinafter.

6

The clevis 57 at the forward end of the splined shaft 55 comprises one part of a universal joint 64 which connects or couples the shaft 55 to a second shaft 65, the shafts 55 and 65 usually being axially aligned and being connected by the universal 64 for conjoint rotation and axial movement. The universal 64, as shown in Figures 2 and 3, includes an intermediate member 66 which is pivotally connected to the clevis 57 by means of a pair of pins 67 which define a pivot axis diametrically of the shaft 55 about which the member 66 may pivot with respect to the clevis 57 and shaft 55. The intermediate member 66 also is pivotally connected to the rearward end of the second shaft 65 by means of a pin 68 which defines a pivot axis diametrically of the shaft 65, the two pivot axes defined by the pins 67 and 68 intersecting one another at right angles. The pins 67 may be press fitted or otherwise secured in diametrically opposed bores in the member 66, and the clevis 57 is preferably provided with sleeve bearings in aligned bores therein rotatably receiving the pins 67. Likewise, the pin 68 may be press fitted or secured in a diametrical bore in the shaft 65 and the member 66 is preferably provided with sleeve bearings in aligned bores therein rotatably receiving the opposite ends of the pin 68. Accordingly, the universal 64 connects the two shafts for simultaneous conjoint rotation and axial movement, the pins 67 and 68 of the universal accommodating angular inclination of the shaft 65 with respect to the shaft 55. In addition, the member 66 is formed with respect to the members 57 and 65 to define clearance between the various members, whereby the members, by virtue of the pins sliding in their bearings, also accommodate lateral or radial offset of the shaft 65 with respect to the shaft 55. Due to the structure of the universal, the same readily accommodates both individual and simultaneous angular and lateral offset of the shafts 55 and 65.

The shaft 65, forwardly of the universal 64, is intimately received within a tubular spindle 69 and at its forward end terminates in a T-shaped end member 70. The member 70 may suitably be formed separately of the shaft 65 and have its stem threaded into the forward end of the shaft axially thereof. The head of the T-shaped member extends diametrically of the shaft 65 and spindle 69 and is of a length greater than the diameter of the shaft to be received at its opposite ends in slots 71 provided in diametrically opposed relation in the spindle 69, the head of the T thus rotatably connecting the shaft and the spindle and the slots accommodating relative axial movement of the two. Preferably, bearing caps 72 are disposed over the ends of the head of the T and each is rotatably supported thereon by means of a ball confined between the respective cap and end of the T head. Forwardly of the slots therein, the spindle 69 is provided with a radial flange 73, and between this flange and an annular end cap 74 secured to the rearward end of the spindle is clamped a bearing assembly 75.

The bearing assembly 75 includes a self-aligning bearing and a pair of thrust bearings, the latter being disposed to opposite sides of the former. The self-aligning bearing may be of any known type and is herein shown as comprising a spherical bearing having an annular inner race 76 and an annular outer race 77, the inner race being longer than the outer race and the bearing surface between the two races being spherical to accommodate tilting or relative angular movement of the races with respect to each other. The outer race 77 is stationarily clamped within the tubular portion 47 of the housing 39 and the inner race 76 loosely surrounds the spindle 69 without normally engaging the same, whereby clearance normally exists between the two, as is indicated at 78. The thrust bearings are clamped to the opposite sides of the inner race 76 of the self-aligning bearing and each comprises, as indicated at the rearward bearing, a pair of annular races 79 and 80 and a plurality of balls 81 located between the radial faces of the two races.

The race 79 adjacent the self-aligning bearing may suitably be counterbored on the face thereof engaging the inner race 76 of the bearing for alignment purposes, but the counterbore is not so deep as normally to permit the race 79 to engage the outer race 77 of the self-aligning bearings, clearance specifically being provided, as is indicated at 82. The opposite radial face of the race 79 is entirely smooth to accommodate radial movement of the race 79 with respect to the bearing balls 81. The bearing balls are retained in place due to their reception within an annular groove provided in the face of the race 80. As thus assembled, the bearings are clamped in place, as above noted, between the flange 73 and the end cap 74 which is detachably secured to the spindle 69. Suitably, the cap 74 is splined or keyed to the spindle 69 and secured thereon by a set screw. To enclose the bearing assembly 75 and to clamp the same in the tubular portion 47 of the housing 39, an annular end cap 83 is secured to the outer surface of the wall 49 of the housing in axial alignment with the portion 47.

In use, as the shafts 55 and 65 are rotated, the spindle 69 is rotated therewith due to the engagement therewith of the T-shaped member 70 carried by the shaft 65. The spindle 69 is rotatably supported by the thrust bearings of the bearing assembly 75, the races 80 thereof being carried by the spindle and the balls 81 accommodating relative rotation between the races 79 and 80. The clearance provided in the universal joint and the clearance at 78 between the spindle and the inner race 76 of the self-aligning bearing accommodate lateral offset of the shaft 65 and spindle 69 with respect to the shaft 55, the races 80 and balls 81 of the thrust bearings in such case moving radially of the races 79. Due to gravity, the shaft 65 and the spindle 69 normally rotate about an axis disposed in spaced parallel relation to the axis of rotation of the shaft 55. In addition to the defined clearance, the pivot axes of and clearance provided in the universal, in conjunction with the spherical movement accommodated by the self-aligning bearing (76, 77) and the clearance at 82 between the races 79 and 77, will accommodate angular inclination or offset of the shaft 65 and spindle 69 with respect to the shaft 55. Also, the aforesaid structural relationship of the components involved will accommodate simultaneous lateral offset and angular inclination of the shaft 65 and spindle 69 with respect to the shaft 55. The reason for accommodating lateral and/or angular offset will become more fully apparent as the description proceeds.

The spindle 69 extends forwardly from the housing 39 to an appreciable length and defines within the interior thereof a guide bore for the reception of the honing tool or mandrel 11. In the art, the word mandrel describes the member which carries the honing stones and this member is specifically indicated, in Figures 2, 4 and 5, at 84. The mandrel 84 comprises a cylindrical shaft provided with bayonet slot means 85 at its rearward end and a head portion at its forward end. The mandrel is adapted to be slidably inserted in the spindle and rotated therein to receive the head of the T-shaped member 70 in the bayonet slots thereof, thus to connect the mandrel to the shaft 65 for conjoint rotation with the shafts 55 and 65 and the spindle 69, and for conjoint axial movement with the shafts 55 and 65. The head portion of the mandrel is indicated at 86 and is shown herein as comprising an enlarged or bulbous cylindrical portion at the outer end of the mandrel. In actual construction, the head 86 may be larger, smaller, or the same size as the shaft portion of the mandrel depending upon the diameter of the bore to be honed. Also, the head portion 86 may be of a length greater or less than that shown herein, depending again upon the nature of a specific honing operation. Irrespective of its diameter and length, the head portion is provided therein with diametrically opposed recesses 87 (see Figures 2, 4 and 5) each of which is relatively wide and defines an inclined base

wall tapering radially inwardly from the rear to the front of the head. Also, the head 86 and the forward portion of the mandrel are provided centrally of the recesses 87 with diametrically opposed longitudinal grooves 88 which extend rearwardly in the shaft into the interior of the spindle 69. The recesses 87 are adapted for the reception therein of complementally formed honing stones 89, each of which has an inclined base wall and an arcuate wall, the outer walls of the two stones defining a cylinder of a greater diameter than that of the head 86. Each stone is fixed to a metallic shoe which is of a width greater than the respective stone and the respective recess 87 to be received at at least one longitudinal edge thereof in a slot 90 formed in the side wall of each recess 87 adjacent and parallel to the base wall thereof. For most honing operations, the provision of a single slot 90 in each recess is adequate to define an interlocking relation between the shoe of the stone and the head of the mandrel for the purpose of retaining the stone in the recess. However, for exceedingly delicate work, a slot 90 may be provided in each side wall of each recess and the stone shoe may be made of a width to enter into both slots. Affixed to each shoe is a retainer or retaining wire 91 which extends rearwardly from the respective stone within a groove 88 in the mandrel so as not to project from the mandrel. Immediately adjacent the forward end of the spindle 69, the retainers 91 are each turned radially outward to be received at the terminal ends thereof in notches provided in the forward end of the spindle (see Figure 4). To lock the stone retainers 91 to the spindle 69, an end cap 92 is mounted on the spindle to overlie the radially disposed terminal ends of the retainers. Preferably, the cap is provided with an inclined slot 93 in the cylindrical wall thereof and a pin 94 is passed through the slot and threaded into the spindle to secure the cap to the spindle while accommodating rotation of the cap. In the forward face thereof, the cap is provided with diametrically aligned slots 95 which are adapted to be aligned with the grooves 88 in the mandrel and the notches in the spindle to accommodate insertion and removal of the retaining wires, thus to accommodate insertion and removal from the spindle of complete mandrel assemblies, the cap being rotatable to move unslotted portions of the cap over the radial portions of the retainer to lock the retainers and the honing stones to the spindle. Preferably, a nose member 96 is secured to the end of the mandrel to retain the stones on the mandrel even if a retainer wire were to break.

Upon assembly of the various components in the manner above described, it is to be appreciated that as the hollow shaft 37 is rotated, by means of the motor 32 through the drive means 34, 35, 36, the shafts 55 and 65, the spindle 69, the mandrel 84 and the stone assembly are rotated conjointly with one another to rotate the stones 89 within a bore in a work piece, the universal 64 and bearing assembly 75 accommodating such angular and lateral movement of the mandrel, spindle and stones as may be required. Then, upon supply of air under pressure to the pneumatic motor 61, the piston rod 60, shaft 55, universal 64, shaft 65 and mandrel 84 (including the nose 96) are moved forwardly with respect to the housing 39, tubular shaft 37, spindle 69 and bearing assembly 75. The spindle cap 92 and retainers 91 retain the stones 89 in a fixed axial relation to the spindle 69 so that the head 86 of the mandrel 84 moves forwardly with respect to the stones. During such movement, the inclined base walls of the recesses 87 in the mandrel head 86 cam the honing stones 89 radially outwardly of the mandrel to move the same into engagement with the wall or surface of the work piece to be honed, the retainers 91 being resilient to accommodate such movement. Due to the fact that the stones are moved outwardly by air pressure through the instrumentalities described, it is to be appreciated that a resilient or cushioning force is ap-

plied to the stones to bias the same outwardly and that the force or pressure exerted on the stones for a given honing operation is constant and uniform. Furthermore, the pressure is readily varied to increase or decrease the biasing force as may be required for different honing operations. For controlling the supply of air to the motor 61, the honing machine of the invention preferably includes a valve 97, suitably a solenoid valve, and an air pressure regulator 98 in the air supply conduit 89, as is shown in Figure 1. For any setting of the regulator 98, a constant supply of air at uniform pressure is supplied to the motor upon opening of the valve 97, and the pressure is readily variable by adjustment of the regulator 98. The valve 97 preferably includes a vent port for relieving air pressure in the motor 61 upon closing of the valve. Upon relief of air pressure, the spring 63 and the motor 61 return the shaft 55, universal 64, shaft 65 and mandrel 84 to their original positions, whereby the stones 89 are moved radially inwardly, due to the engagement of the shoes thereof in the slots 90 in the mandrel head 86, to free the stones from the work piece.

After the honing stones have worked upon the walls of the bore to be honed, it is necessary to gauge the bore to insure accuracy of the bore. As pointed out hereinbefore, pneumatic plug gauges are ideally suited for such purpose, but use of the gauges has heretofore presented a deterrent to high production because of a necessity for gauging the bore in the work piece separately of the honing machine and in a distinct, individual operation. According to the present invention, this problem is obviated by incorporation of the gauge directly in the honing machine. Specifically, as is shown in Figure 2, the spindle 69 of the machine of the invention is extended to an appreciable length outwardly of the housing 39 to define a cylindrical mounting surface. Upon this surface, we mount the tubular gauge plug 100 of a pneumatic gauge. The plug 100 is confined between the housing cap 83 and spindle cap 92 and is preferably mounted for rotation with respect to the spindle 69, so that the spindle 69 may rotate within the plug while the plug is held stationary. The inner diameter of the plug 100 is preferably greater than the outer diameter of the spindle 69 to accommodate bearings 103 which rotatably support the plug on the spindle. The plug 100 includes a radial flange 104 having a generally radial bore 105 therein constituting the air inlet to the plug, an air supply conduit or hose 106 communicating with the bore and being connected to the flange 104 by a fitting 107. Suitably, the plug may be held against rotation by means of a rod 108 projecting from the housing 39 or cap 83 and engaging the fitting 107. As is customary, the plug 100 is provided in the cylindrical body thereof with one or more longitudinal passages or veins 101, each of which communicates at its opposite ends with the air inlet 105 and with a radial bore 109 through which air may escape into the space between the plug and the honed bore, the rate of escape of air comprising the measurable function for gauging of the bore. For indicating the gauge diameter of the bore, an air comparator 110, as shown in Figure 1, is included in the air supply conduit 106, the comparator being a known measuring instrument for comparing the rate of escape of air from the plug 100 to a known standard, the comparator including a properly marked or calibrated scale and a dial hand movable over the scale to indicate whether the diameter of the bore is within established tolerances, or smaller or larger.

Referring now particularly to Figure 1 of the drawings, we will describe the operation of the honing machine of the invention in conjunction with certain control instrumentalities to render operation fully automatic. As shown in dotted lines, the machine includes a control panel 111 which may be mounted on a suitable portion of the machine to be readily accessible to the machine operator. This panel includes three series of control instrumentalities for four functions, namely, an indicator light 112,

a start or on switch button 113 and a reverse, stop, or off switch button 114, one each of the components 112, 113 and 114 being provided for the hydraulic pump 15, the coolant pump 29, the fixture motor 21 and the honing apparatus 10. To commence operation of the machine, the start buttons 113 for the hydraulic and coolant pumps are depressed, operation for the pumps being indicated by illumination of the respective lights 112. Both pumps may suitably be operated continuously and are turned on at the beginning of a work shift and are left on and running until the end of the shift, or until the machine is to be readjusted for a different honing operation. Work pieces 22 are then inserted in the fixture 20 and secured therein by the locking means 25, 26, 27. As will be appreciated, insertion of the work pieces may be accomplished manually or automatically by known apparatus. For clarity, reference is made herein to manual loading only. When the fixture is loaded, the fixture start button 113 is depressed to energize the motor 21, the motor 21 automatically indexing the fixture to dispose the bore in one work piece generally in axial alignment with the spindle and shafts of the honing apparatus. Indexing of the fixture is automatically accomplished, when the fixture control buttons 113 and 114 are depressed alternately, by means of conventional stops and control means located in predetermined positions according to practices well known in the art, actuation of the motor 21 being effective by fluid under pressure from the hydraulic pump 15 under the master control of the fixture control buttons.

With a work piece properly mounted in the fixture 20 and aligned with the honing apparatus 10, honing is commenced by depression of the hone start button 113. This first results in the supply of hydraulic fluid under pressure from the pump 15 to the hydraulic motor 13 causing the motor to move the apparatus 10 toward the work piece 22. As the nose 96 of the honing tool 11 engages the work piece, the tool is guided into the bore in the work piece by its tapered nose. If the axis of the work piece is not perfectly aligned with the normal axis of rotation of the honing tool, spindle and shafts, the nose of the tool and the tool itself guide and effect adjustment of the tool and its spindle and shafts into perfect axial alignment with the bore in the work piece, the clearance provided in the honing apparatus, at 78 and 82 in the bearing assembly 75 and in the universal 64, readily accommodating such adjustment. Generally, the degree of misalignment between the bore of the work piece and the normal axis of rotation of the honing tool is very slight, but even slight variations in alignment can be enough to result in an entirely unsatisfactory honing operation and in a high percentage of rejected work pieces. Misalignment may result from slightly imperfect location of the bore in the work piece and/or inability to index the work pieces to the exacting degree required, misalignment residing in radial or lateral offset and/or angular inclination of the axis of the bore in the work piece with respect to the normal axis of rotation of the honing tool. To exhibit the finiteness of dimensional variation involved, we have found, in conjunction with the work pieces specifically referred to herein, that radial offset is within the limit of  $\frac{1}{2}$  inch from a given axis and that angular inclination does not result in a radial displacement from the given axis in excess of .010" within the length of the portion of the bore to be honed. Yet, this is enough to disrupt the honing operation. By providing the universal 64 and by providing clearance in the universal and at 78 and 82 in the bearing assembly 75, the present invention accommodates such variations in alignment and, accordingly, makes accommodation for the honing tool to align itself exactly with the axis of the bore to be honed to effect a perfect honing of the bore. While no particular limits are to be placed on the clearance and movements accommodated by the machine of the invention, we have found, for the alignment variations above stated, that an annular

clearance of  $\frac{1}{16}$ " on the radius in the universal, an annular clearance of  $\frac{1}{32}$ " on the radius at 78 and a clearance of .001 inch at 82 (in consideration of the length of the mandrel), are entirely adequate for the specific purpose. Accordingly, as the honing apparatus 10 is moved forwardly by means of the hydraulic motor 13, the honing tool enters into and automatically aligns itself with the bore in the work piece.

As the honing apparatus 10 moves forwardly, a trip bar 115, suitably carried by the housing 39, engages a first control switch 116 to close an electric circuit to a timer 117, which may, for example, be mounted adjacent the control panel 111. The timer 117 is adapted to be set for a predetermined time interval constituting the time normally required to perform a given honing operation, and the switch 116 and timer 117 are included in the circuits of the spindle drive motor 32 and the solenoid valve 97. The switch 116 is adapted to close the circuit, whereupon the circuit is maintained closed by the timer for the said predetermined interval, during which interval the solenoid valve 97 is held opened and the motor 32 is operated. Preferably, the switch 116 is located to accommodate insertion of the stones 89 of the honing tool at least partially into the portion of the bore to be honed before the switch is closed. Upon operation of the motor 32, the honing tool is rotated thereby within the bore. At this same time, air is supplied at a predetermined pressure through the regulator 98 to the pneumatic motor 61 which acts in the manner described hereinbefore to bias the stones 89 of the honing tool radially outwardly, under uniform constant, resilient pressure, into engagement with the walls of the portion of the bore to be honed. During this time, the honing apparatus 10 continues to move forwardly until the trip bar 115 engages a second control switch 118 which is connected in a control circuit for the hydraulic motor 13, the circuit, its components and operation being well known to those skilled in the art and therefore not specifically shown herein. The switch 118 is so located that the honing tool reaches one end of the portion of the bore to be honed when the trip bar 115 closes the switch, the switch in turn closing a suitable circuit to cause reversal of the hydraulic motor 13, whereupon the honing apparatus travels rearwardly on its carriage rods 42 until the trip bar 115 engages a third control switch 119. The switch 119, like the switch 118, is included in the control circuit for the hydraulic motor 13, so that as the switch 119 is closed, operation of the hydraulic motor is again reversed to move the honing apparatus forwardly toward the work piece. By positioning of the switches 118 and 119 to be closed by the trip bar 115 when the honing tool is at the opposite ends of the portion of the bore to be honed, automatic reciprocation of the honing tool within the portion of the bore to be honed is accommodated. Such reciprocation of the apparatus takes place automatically for the interval of time set by the timer 117. Thus, for a predetermined time interval, the honing stones are biased into engagement with the work piece and are simultaneously rotated and reciprocated within the portion of the bore to be honed to perform a highly efficient honing operation.

Upon expiration of the interval for which the timer 117 was set, the timer automatically opens the circuit to the motor 32, solenoid valve 97 and control switch 118. Rotation of the honing tool is thus discontinued and the stones are released and returned to their radially inward position by means of the return spring 63 in the pneumatic motor 61. In addition, when the timer opens the said circuits, the control switch 119 is conditioned, suitably by a time delay relay (not shown) associated with the timer, for operation only during a very short additional period of time. If the honing apparatus 10 is moving rearwardly when the time interval of operation expires, the bar 115 will again trip the switch 119 to result in forward movement of the apparatus 10. If the honing apparatus 10 is moving forwardly when the timer 117

opens the circuit, the apparatus will continue to move forwardly. In either case, as the apparatus 10 moves forwardly, the trip bar rides over the switch 118 since the circuit of this switch is now open, to move the pneumatic plug gauge 100 into the now honed portion of the bore in the work piece. As the plug 100 is moved into the honed bore, the escape of air through the ports 109 is restricted to afford an indication of the accuracy of the honed bore on the comparator 110. As is known, the comparator will indicate whether the bore is within tolerances, or over or under size. When the plug gauge has been entered to a predetermined extent into the honed portion of the work piece bore, the trip bar 115 closes a fourth control switch 120 which duplicates the function of the switch 118 to effect reversal of the hydraulic motor 13 and rearward movement of the apparatus 10.

As the apparatus moves rearwardly, the trip bar 115 rides harmlessly over the switches 116, 118 and 119 until the same closes a fifth control switch 121 which serves to stop or discontinue operation of the hydraulic motor 13, to recondition the apparatus for a repeat operation and to accommodate operation of the fixture moving motor 21. Preferably, the control circuit includes switch means in conjunction with the motor 21 and switch 121, which prevents movement of the honing apparatus 10 while the fixture is being moved and vice versa.

To accommodate use of the machine for a wide variety of honing operations, the switches 116, 118, 119 and 120 are adjustably mounted on the machine.

In use and operation then, the operator first sets the pumps 15 and 29 in operation by depressing the appropriate start buttons 113. Then, the operator loads two work pieces into the carriage of the fixture 20. Since one of the work pieces will always be indexed, the machine is set to start honing. The timer is set for a predetermined time interval, for example, 1 to 12 seconds, in which the honing operation is to take place. The operator then depresses the honing start button 113, whereupon the apparatus 10 automatically moves forward to position and automatically align the honing tool in the bore, the electric and pneumatic motors are automatically energized to effect honing, the honing tool is automatically reciprocated in the bore, the air gauge is automatically moved into the bore and the honing apparatus is automatically retracted or withdrawn. As the air gauge moves into the bore, the operator observes the comparator to determine the accuracy of the honed bore. Assuming the bore is within tolerances, the operator, upon automatic retraction of the honing apparatus, indexes the fixture 20 by depressing the fixture control button and then repeats the honing operation by depressing the hone start button. While the honing operation on the second work piece is taking place, the operator removes the first work piece from the fixture and inserts a new work piece. At the same time, the operator observes the comparator to see that the second work piece is accurately honed. If desired, to assist the operator in his observance of the gauge, audible signal means could be incorporated in the gauging apparatus to indicate work pieces that were not within tolerances. Upon completion of the second honing operation, the operator again indexes the fixture 20 and reinitiates the honing operation. Accordingly, it is to be appreciated that the speed of operation is great and that very high production rates can readily be maintained. If a bore is oversized, as indicated by the comparator, the operator quickly rejects the work piece. If the bore is undersized, the operator may directly rehone the work piece by immediately repeating the honing operation, for the same or a greater or lesser time, by resetting the timer if necessary and depressing the hone start button without indexing the fixture. This too assures attainment of maximum production rates with a minimum of rejections and tedious reworking.

From the foregoing, it is to be appreciated that the

present invention affords a fully automatic honing machine insuring attainment of maximum production rates while honing work pieces to a most precise degree. The honing tool is self-aligning in the bore of the work piece so that honing must take place concentrically. During honing, the honing stones are uniformly and resiliently biased into engagement with the work piece at constant pressure, and the amount of pressure may very readily be varied as may be desired or necessary. Gauging of the work pieces is effected at high speed and without loss of time and needless handling of the work pieces. And all of these features lead to the provision of a high speed honing tool requiring only a single operator for the entire honing operation.

While we have described what we regard to be a preferred embodiment of our invention, it will be appreciated by those skilled in the art that various changes, rearrangements and modifications may be made therein without departing from the scope of the invention, as defined by the appended claims.

We claim:

1. In a honing machine having a rotatable hone assembly, a drive shaft for the assembly, a universal joint connecting said shaft and the assembly, and bearing means rotatably supporting the assembly, said bearing means having clearances therein and including bearing surfaces accommodating rotary lateral and angular movement of the assembly, said universal joint accommodating said angular movement and having radial clearance therein accommodating said lateral movement, whereby the assembly is free to move angularly and radially relative to said shaft to align itself with the work to be honed.

2. In a honing machine, a drive shaft, a driven spindle, a universal joint coupling said shaft and said spindle for conjoint rotation, said universal joint accommodating angular offset of the axes of said shaft and said spindle and having radial clearance therein accommodating radial offset of said axes, and a bearing assembly rotatably supporting said spindle, said bearing assembly including thrust bearing means mounting said spindle for rotation and for limited radial movement and self-aligning bearing means having an angularly movable race mounting said thrust bearing means for angular movement, whereby said bearing assembly accommodates radial and angular offset of said axes.

3. In a honing machine having a rotatable and axially movable hone assembly including a rotatable spindle and honing stones connected thereto, the improvement comprising a pneumatic plug gauge rotatably mounted on the spindle adjacent the stones and retained thereon against relative axial movement to be moved by the assembly directly into a bore in a work piece after honing thereof to gauge the honed bore prior to disassociation of the work piece and the hone assembly, said gauge being of a smaller diameter than the honed bore and being spaced from the wall of the bore.

4. In a honing machine, a rotatable hollow spindle, bearing means rotatably supporting said spindle and accommodating radial and angular offset of said spindle, a first shaft slidably mounted in said spindle for conjoint rotation with and relative axial movement with respect to said spindle, a mandrel slidably mounted in said spindle and detachably connected to said shaft, at least one honing stone slidably carried by said mandrel and detachably connected to said spindle, said mandrel and said stone having cooperating cam surfaces to effect radially outward movement of said stone upon axial movement in one direction of said shaft and said mandrel with respect to said spindle and said stone, a rotatable and slidable drive shaft, a universal joint coupling said shafts, said universal joint accommodating angular offset and having radial clearance therein to accommodate radial offset of said spindle, said mandrel and said first shaft with respect to said drive shaft, means for rotating said drive shaft to rotate said spindle, said first shaft, said mandrel and said stone, and

a fluid pressure operated motor coupled to said drive shaft and operable under fluid pressure to move said drive shaft, said first shaft and said mandrel in said one axial direction to bias said stone radially outward.

5. In a honing machine, a rotatable hollow spindle, a bearing assembly supporting said spindle, said bearing assembly including a thrust bearing rotatably supporting said spindle and accommodating radial offset of the axis of rotation thereof and a self-aligning bearing accommodating angular offset of the axis of rotation thereof, a first shaft slidably mounted at one end thereof in one end of said spindle for conjoint rotation with and relative axial movement with respect to said spindle, a mandrel slidably mounted at one end thereof in the other end of said spindle, said mandrel and said shaft being detachably connected at the adjacent ends thereof for conjoint movement, a plurality of honing stones slidably carried on said mandrel adjacent the opposite end thereof, said stones being detachably connected to said other end of said spindle, said mandrel and said stones having cooperating cam surfaces to effect movement of said stones radially outwardly of said mandrel and said spindle upon axial movement in one direction of said shaft and said mandrel with respect to said spindle and said stones, a rotatable and slidable drive shaft juxtaposed to said first shaft, said first shaft, said mandrel and said stones, a universal joint coupling said shafts at the adjacent ends thereof, said universal joint accommodating angular offset and having radial clearance therein to accommodate radial offset of the axis of rotation of said spindle, said mandrel and said first shaft with respect to said drive shaft, means for rotating said drive shaft to rotate said spindle, said first shaft, said mandrel and said stones, and a fluid pressure operated motor having a shaft rotatably coupled to said drive shaft and operable under fluid pressure to move said drive shaft, said first shaft and said mandrel in said one axial direction to bias said stones radially outwardly of said spindle for engagement with the work to be honed at constant uniform pressure.

6. In a honing machine, a rotatable hollow spindle, bearing means supporting said spindle adjacent one end thereof, a mandrel slidably mounted in said spindle for conjoint rotation therewith, at least one honing stone slidably mounted on said mandrel adjacent the opposite end of said spindle and connected to said spindle, a hollow fluid pressure operable plug gauge mounted on said spindle between said bearing means and said stone and retained thereon against relative axial movement, bearing means rotatably supporting said gauge on said spindle and means retaining said gauge against rotation, said mandrel and said stone having cooperable cam surfaces to effect movement of said stone radially outwardly beyond said gauge upon sliding movement of said mandrel in one direction with respect to said spindle and said stone, and a fluid pressure operated motor operatively associated with said mandrel and operable under fluid pressure to move said mandrel in said one direction to bias said stone radially outwardly beyond said gauge to engage a work piece to be honed at constant uniform pressure, said spindle being axially movable to dispose said stone in engagement with the work piece and being further movable to dispose said gauge adjacent the honed portion of the work piece to gauge the same prior to disassociation of the work piece and the honing stone, said gauge having clearance relative to the honed surface of the work piece and having an outlet juxtaposed to the said surface, said gauge being connected to a fluid pressure source to discharge fluid under pressure from said outlet against the said honed surface, the rate of escape of fluid into the space between the gauge and the said surface being a function of the distance between said outlet and the said surface to afford a gauging function.

7. In a honing machine, a rotatable tubular spindle, a shaft slidably mounted in said spindle for conjoint rotation therewith, a mandrel slidably mounted in said spin-

dle and detachably connected to said shaft, bearing means supporting said spindle adjacent one end thereof rotatably to support said spindle, said shaft and said mandrel, said mandrel extending beyond the opposite end of said spindle, a plurality of honing stones slidably mounted on the extending portion of said mandrel and detachably connected to said spindle at said opposite end of said spindle, a tubular pneumatic plug gauge rotatably mounted on said spindle between said bearing means and said stones and retained thereon against relative axial movement, bearing means rotatably supporting said gauge on said spindle and means retaining said gauge against rotation, said stones and said mandrel having cooperating cam surfaces to effect movement of said stones radially outwardly beyond said gauge upon sliding movement of said shaft and said mandrel in one direction with respect to said spindle and said stones, means for rotating said spindle, said shaft, said mandrel and said stones, a pneumatic motor having a shaft operatively associated with said shaft for relative rotation and conjoint sliding movement, said motor being pneumatically operable to move said shaft and said mandrel in said one direction during rotation of said spindle, said shaft, said mandrel and said stones to bias said stones radially outwardly beyond said gauge to engage the walls of a bore in a work piece to be honed, and means for moving said spindle, said mandrel, said stones and said gauge bodily into the bore to be honed to hone the bore by means of said stones and immediately to gauge the honed bore by means of said gauge, said gauge being of a diameter smaller than the honed bore and being spaced from the wall of the bore, said gauge having an outlet in the peripheral surface thereof to be disposed within the honed bore and being connected to a source of air under pressure to discharge air from said outlet into the space between said gauge and the wall of the bore, the rate of escape of fluid into the said space being a function of the radial dimension of the said space to afford a gauging function.

8. In a honing machine, a rotatable hollow spindle, bearing means supporting said spindle adjacent one end thereof and accommodating lateral and angular offset of the axis of rotation thereof, a mandrel slidably mounted in said spindle for conjoint rotation therewith, at least one honing stone slidably mounted on said mandrel adjacent the opposite end of said spindle and connected to said spindle, a hollow fluid pressure operable plug gauge mounted on said spindle between said bearing means and said stone and retained thereon against relative axial movement, bearing means rotatably supporting said gauge on said spindle and means retaining said gauge against rotation, said mandrel and said stone having cooperating cam surfaces to effect movement of said stone radially outwardly beyond said gauge upon sliding movement of said mandrel in one direction with respect to said spindle and said stone, a fluid pressure operated motor operatively associated with said mandrel and operable under fluid pressure to move said mandrel in said one direction to bias said stone radially outwardly beyond said gauge to engage a work piece to be honed at constant uniform pressure, and means for moving said spindle axially toward a work piece having a bore therein to be honed, said bearing means accommodating self-alignment of said stone in the bore, said means for axially moving said spindle moving said stone into the bore to effect honing and subsequently moving the spindle further into the bore to dispose said gauge in the honed bore prior to disassociation of the work piece and the honing stone, said gauge being of a diameter less than the bore and being spaced from the wall of the bore, said gauge having an outlet in the peripheral surface thereof to be disposed in the honed bore and being connected to a fluid pressure source to discharge fluid under pressure into the space between said outlet and the wall of the bore, the rate of escape of fluid into the said space being a function of

the radial dimension of the said space to afford a gauging function.

9. In a honing machine, a rotatable hollow spindle, a shaft slidably mounted in said spindle for conjoint rotation therewith, a mandrel slidably mounted in said spindle and detachably connected to said shaft, bearing means supporting said spindle adjacent one end thereof rotatably to support said spindle, said shaft and said mandrel, said bearing means including a thrust bearing rotatably supporting said spindle and accommodating radial offset of the axis of rotation thereof and a self-aligning bearing accommodating angular offset of the axis of rotation thereof, said mandrel extending beyond the opposite end of said spindle, a plurality of honing stones slidably mounted on the extending portion of said mandrel and detachably connected to said spindle at said opposite end of said spindle, a hollow plug gauge rotatably mounted on said spindle between said bearing means and said stones, said stones and said mandrel having cooperating cam surfaces to effect movement of said stones radially outwardly beyond said gauge upon sliding movement of said shaft and said mandrel in one direction with respect to said spindle and said stones, means for rotating said spindle, said shaft, said mandrel and said stones, a fluid pressure operated motor having a shaft operatively associated with said shaft for relative rotation and conjoint sliding movement, said motor being operable under fluid pressure to move said shaft and said mandrel in said one direction during rotation of said spindle, said shaft, said mandrel and said stones to bias said stones radially outwardly beyond said gauge to engage the walls of a bore in a work piece to be honed, and means for moving said spindle, said mandrel, said stones and said gauge bodily into the bore to be honed to hone the bore by means of said stones and immediately to gauge the honed bore by means of said gauge, said bearing means accommodating self-alignment of said stones and said gauge in the bore.

10. In a honing machine, a rotatable hollow spindle, a bearing assembly supporting said spindle adjacent one end thereof, said bearing assembly including a thrust bearing rotatably supporting said spindle and accommodating radial offset of the axis of rotation thereof and a self-aligning bearing accommodating angular offset of the axis of rotation thereof, a first shaft slidably mounted at one end thereof in one end of said spindle for conjoint rotation with and relative axial movement with respect to said spindle, a mandrel slidably mounted at one end thereof in the other end of said spindle, said mandrel and said shaft being detachably connected at the adjacent ends thereof for conjoint movement, a plurality of honing stones slidably mounted on said mandrel adjacent the opposite end thereof, said stones being detachably connected to said other end of said spindle, a hollow fluid pressure operable plug gauge rotatably mounted on said spindle between said bearing assembly and said stones, said mandrel and said stones having cooperating cam surfaces to effect movement of said stones radially outwardly beyond said gauge upon axial movement of said shaft and said mandrel in one direction with respect to said spindle and said stones, a rotatable and slidable drive shaft juxtaposed to said first shaft, said first shaft, said mandrel and said stones, a universal joint coupling said shafts at the adjacent ends thereof, said universal joint accommodating angular offset and having radial clearance therein to accommodate radial offset of the axis of rotation of said spindle, said mandrel and said first shaft with respect to said drive shaft, means for rotating said drive shaft to rotate said spindle, said first shaft, said mandrel and said stones, a fluid pressure operated motor having a shaft rotatably coupled to said drive shaft and operable under fluid pressure to move said drive shaft, said first shaft and said mandrel in said one axial direction to bias said stones radially outwardly beyond said gauge for engagement with the work to be honed at constant uniform pressure, and means for moving the

17

above defined structure toward a work piece having a bore therein to be honed, said bearing assembly and said universal joint accommodating self-alignment of the axis of rotation of said spindle, said first shaft, said mandrel and said stones with the axis of the bore to be honed, said last-named means moving said stones into the bore to effect honing of the bore and moving said gauge into the honed bore to gauge the same.

11. In a honing machine, a base, a housing slidably mounted on said base for reciprocal movement in a given path, a first fluid pressure operated motor mounted on said base and operatively associated with said housing for moving said housing in said path, a drive shaft, bearing means rotatably and slidably supporting said drive shaft in said housing, drive means on said housing for rotating said drive shaft, a second fluid pressure operated motor on said housing operatively associated with said drive shaft and operable under fluid pressure to move said drive shaft axially in one direction, a hollow spindle mounted at one end thereof in said housing and extending outwardly of said housing, a bearing assembly supporting said spindle at said one end thereof in said housing and accommodating angular and radial offset of the axis of said spindle with respect to the axis of said drive shaft, a second shaft slidably mounted in said spindle axially thereof and coupled to said spindle for conjoint rotation therewith, a universal joint coupling said drive shaft and said second shaft, said universal joint accommodating angular offset and having radial clearance therein to accommodate radial offset of said spindle and said second shaft with respect to said drive shaft, a mandrel slidably mounted in said spindle and detachably connected to said second shaft for conjoint rotation with said spindle and said shafts, said mandrel extending beyond the outer end of said spindle, a plurality of honing stones slidably mounted on the extension of said mandrel and detachably connected to the outer end of said spindle, a fluid pressure operable plug gauge rotatably mounted on the extension of said spindle between said bearing assembly and said stones, said stones and said mandrel having cooperating cam surfaces to effect radially outward movement of said stones beyond said gauge upon sliding movement of said mandrel and said shafts in said one direction, and control means for operating said fluid pressure operated motors and said drive means comprising a first switch controlling energization of said first fluid pressure operated motor to move said housing and said spindle toward a work piece having a bore to be honed, said bearing assembly accommodating self-alignment of said spindle, said second shaft, said mandrel, said stones and said gauge with the axis of the bore, a second switch mounted on said base controlling energization of said drive means and said second fluid pressure operated motor, a trip bar on said housing for tripping said second switch, a timer cooperable with said second switch to control the duration of energization of said drive means and said second fluid pressure operated motor, a third switch mounted on said base forwardly of said second switch and engageable by said trip bar, said third switch cooperating with said first switch and said first fluid pressure operated motor to reverse the direction of movement of said housing, a fourth switch mounted on said base rearwardly of said third switch and engageable by said trip bar on reverse movement of said housing, said fourth switch cooperating with said first and third switches and said first fluid pressure operated motor again to move said housing toward the work piece, said timer controlling the function of said third and fourth switches to energize said first fluid pressure operated motor to move said housing toward the work piece beyond said third switch upon expiration of the duration of energization of said drive means and said second fluid pressure operated motor, and a fifth switch mounted on said base forwardly of said third switch and duplicating the function of said third switch, said control means upon closing

18

ing of said second switch controlling operation of said fluid pressure operated motors and said drive means to move said stones into the bore to be honed, to effect radial expansion and rotation of said stones to hone the bore, simultaneously to reciprocate the stones in the bore, to discontinue honing upon expiration of a predetermined time interval, to move said gauge into the honed bore, and thereafter to withdraw said gauge and said stones from the bore.

12. In a honing machine, a rotatable and axially movable spindle, bearing means supporting the spindle adjacent one end thereof, honing stones connected to said spindle adjacent the opposite end thereof, a fluid pressure operable plug gauge rotatably mounted on said spindle between said bearing means and said stones and retained thereon against relative axial movement, means retaining said gauge against rotation, said spindle being axially movable to insert said stones into a bore to be honed and being further movable to insert said gauge into the honed bore, said gauge being of a smaller diameter than the honed bore to be spaced from the wall of the bore, said gauge being connected to a fluid pressure source and having an outlet in the peripheral surface thereof to be disposed in the bore, the rate of escape of fluid from said outlet into the space between the peripheral surface of said gauge and the wall of the honed bore being a function of the radial dimension of the said space to afford a gauging function.

13. In a honing machine, a drive shaft, a driven spindle, a universal joint coupling said shaft and said spindle for conjoint rotation, said universal joint accommodating angular offset of the axes of said shaft and said spindle and having radial clearance therein accommodating radial offset of said axes, and a bearing assembly rotatably supporting said spindle, said bearing assembly including thrust bearing means mounting said spindle for rotation and for limited radial movement and self-aligning bearing means comprising an angularly movable race having radial clearance relative to said spindle and mounting said thrust bearing means and said spindle for angular movement, said bearing assembly accommodating radial and angular movement of said spindle to accommodate radial and angular offset of said axes of said shaft and said spindle.

14. In a honing machine having a rotatable hone assembly and means adapted to position a work piece generally in alignment with the axis of the assembly, the improvement comprising bearing means supporting the assembly and accommodating at all times radial and angular offset of the axis of rotation of the assembly for facilitating exact alignment of the assembly with each work piece to be honed, said bearing means comprising a spherical bearing freely encircling the hone assembly and including a stationary outer race and an angularly movable inner race, said inner race having an inner diameter greater than the outer diameter of said assembly and being spaced freely therefrom to accommodate radial movement of said assembly, and a pair of thrust bearings engaging said inner race of said spherical bearing at the opposite ends thereof, said thrust bearings rotatably mounting the hone assembly on the inner race of said spherical bearing and each including a pair of races, one fixed to said inner race of said spherical bearing and the other fixed to the hone assembly, and a plurality of ball bearings between said races, said last-named races and said ball bearings accommodating relative rotation and relative radial movement between the races of said thrust bearings and between said inner race of said spherical bearing and the hone assembly, said races of said thrust bearings being freely spaced from said stationary race of said spherical bearing to accommodate angular movement of the hone assembly, said thrust bearings and the inner race of said spherical bearing relative to said stationary race of said spherical bearing whereby the hone assembly is rotatably supported by said

bearing means with freedom at all times for radial and angular offset of the axis of rotation thereof.

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