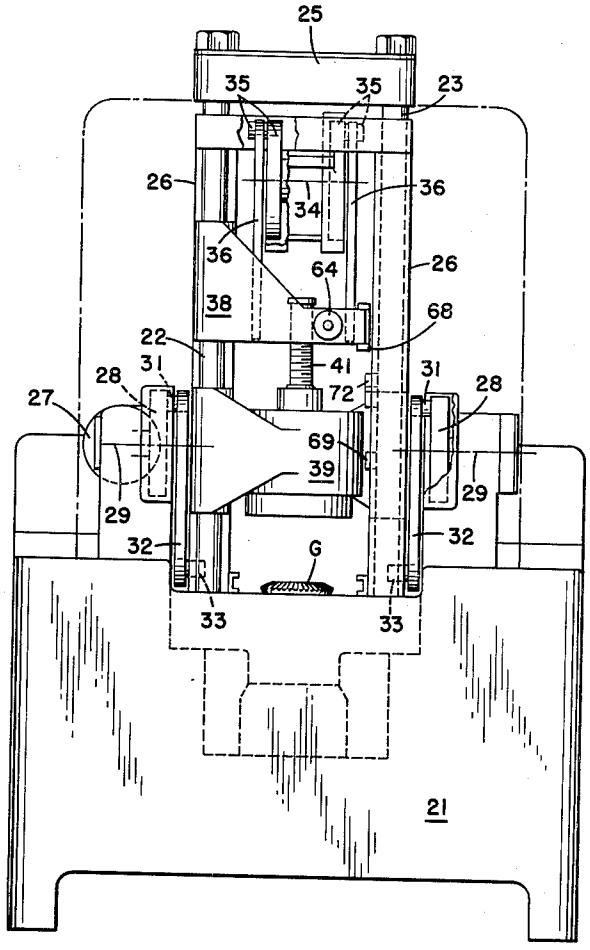
Nov. 7, 1961 R. V. ADAIR ET AL 3,007,823

METHOD AND APPARATUS FOR QUENCH HARDENING

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6 Sheets-Sheet 1

FIG. 1



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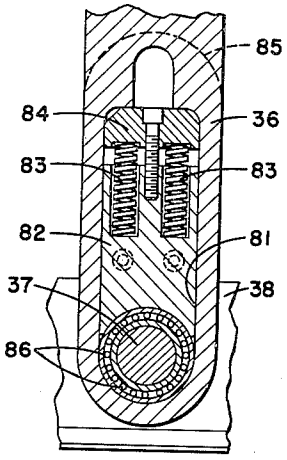


FIG.3

FIG.2

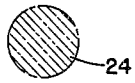
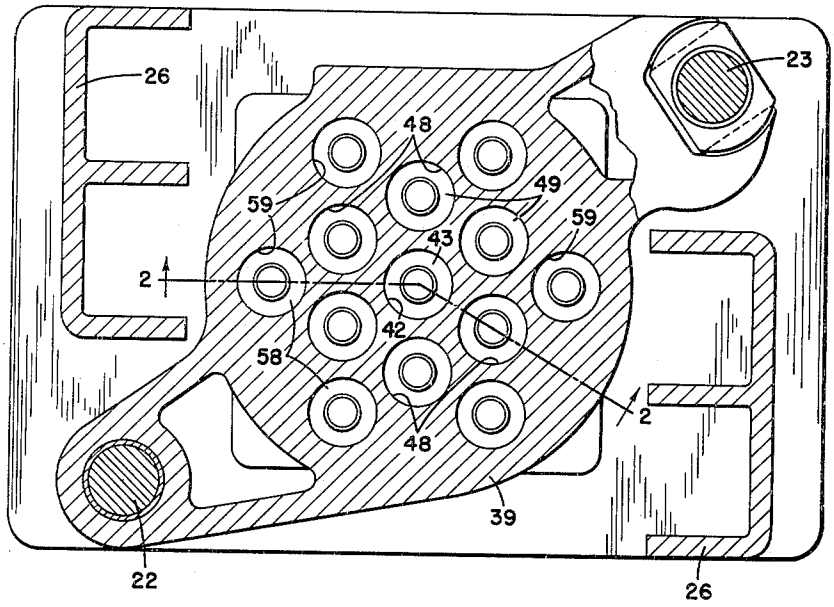


FIG. 4



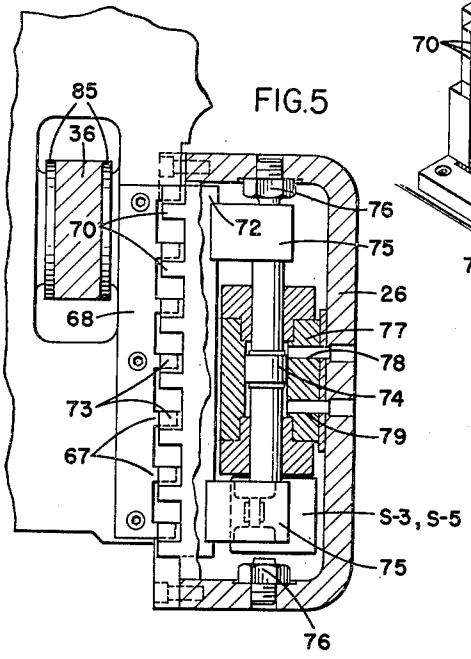


FIG. 5

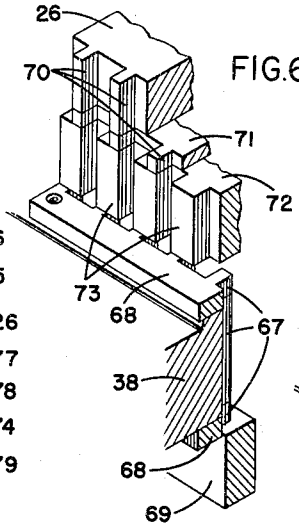


FIG. 6

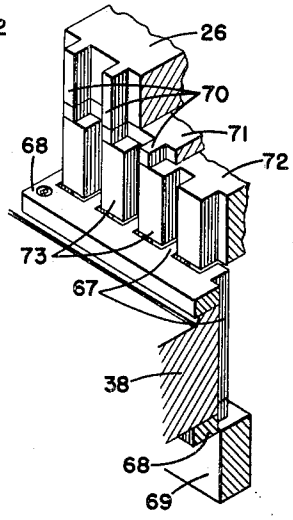


FIG. 7

FIG. 8

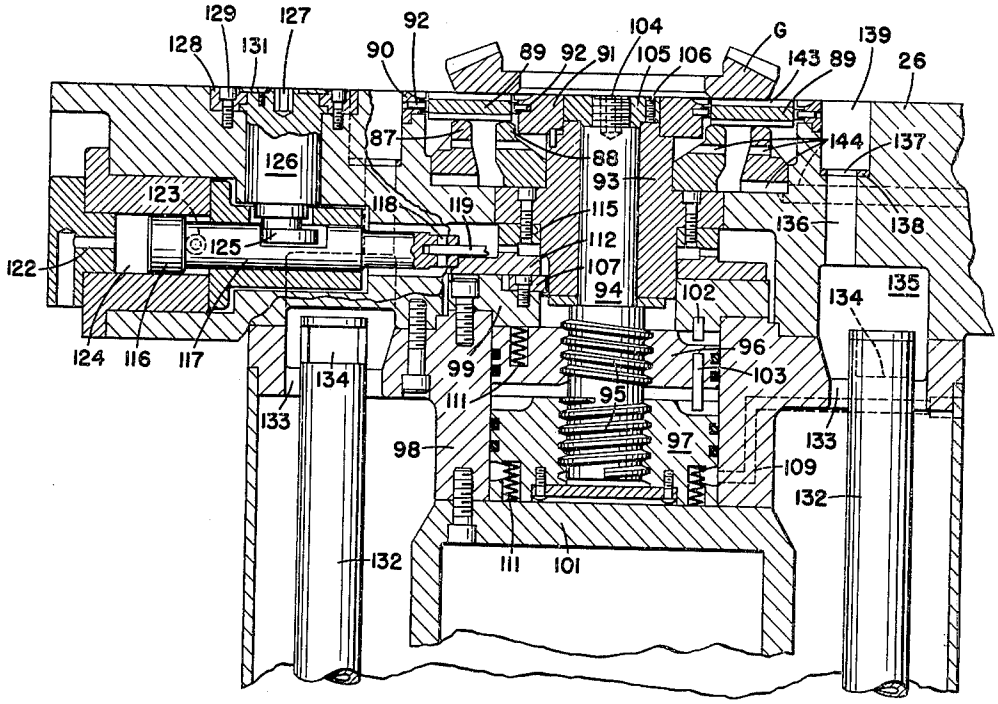
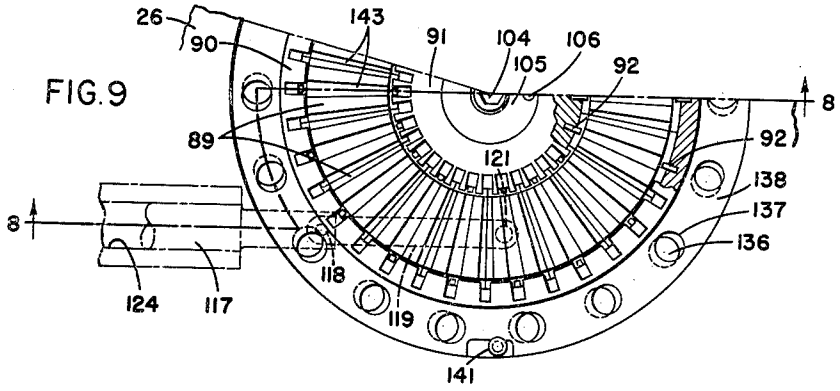


FIG. 9



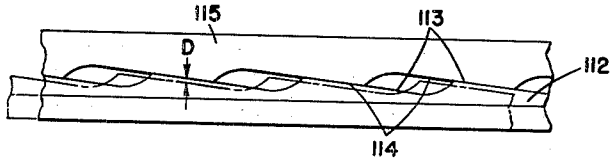


FIG. 10

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FIG. 11

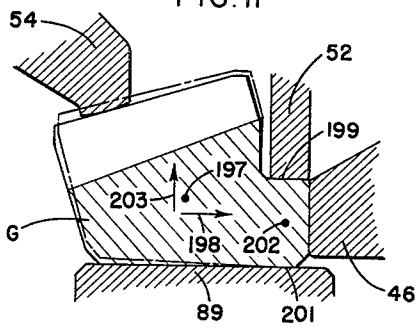
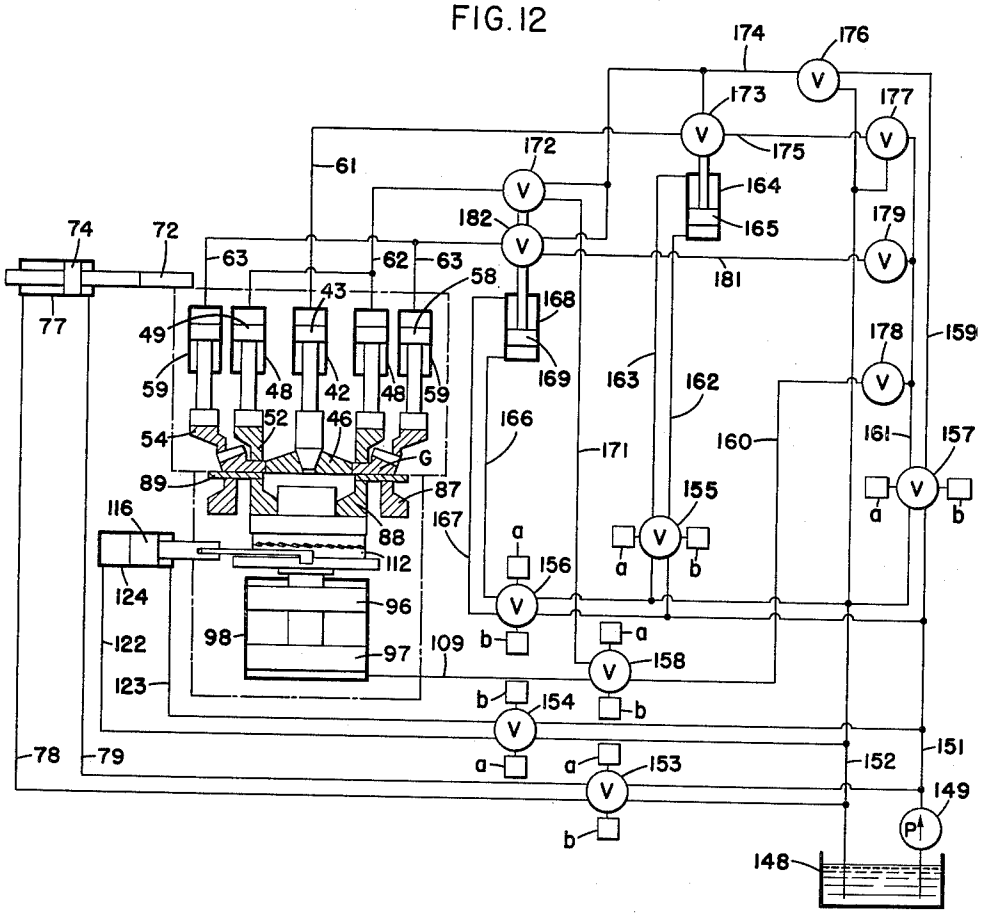


FIG. 12

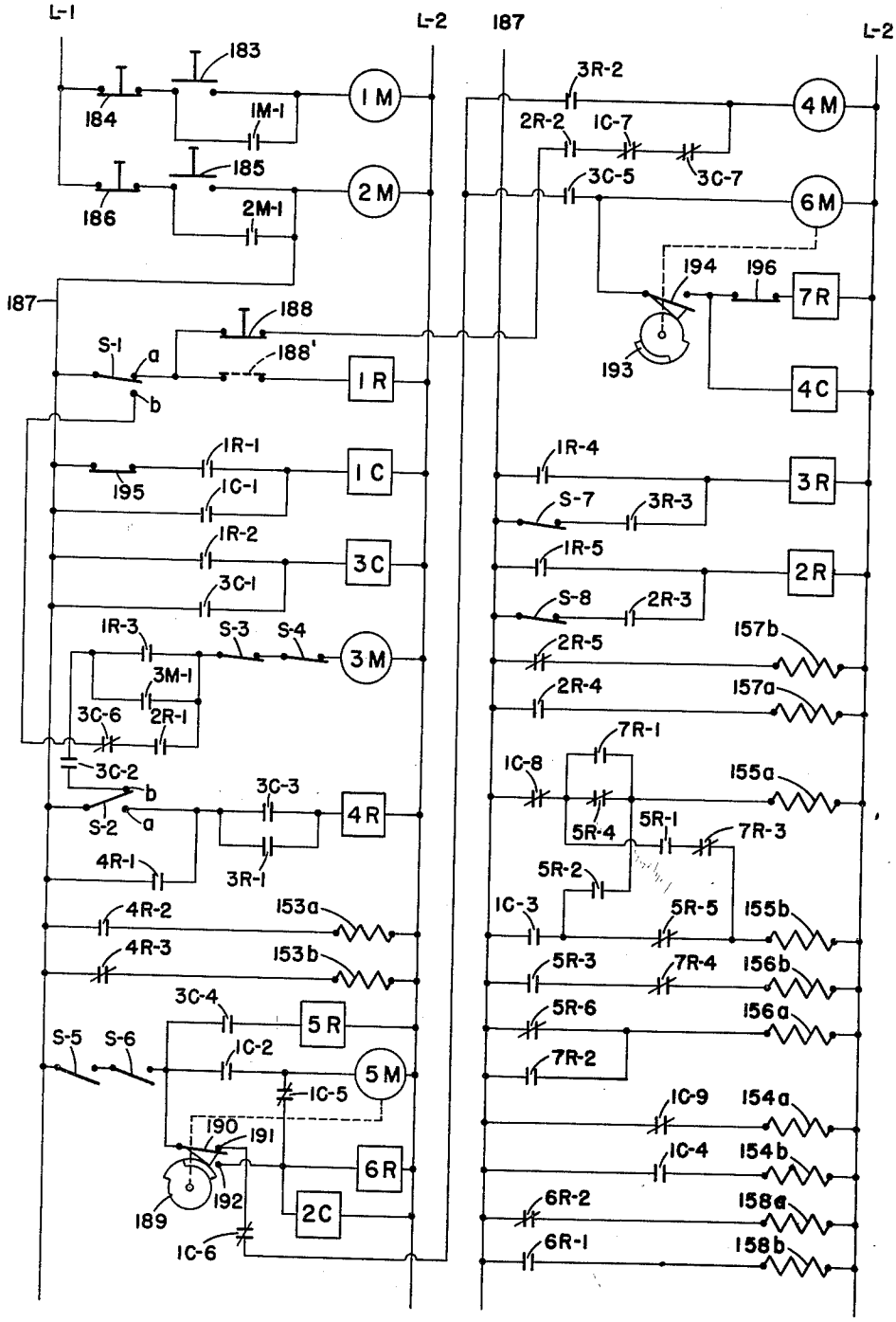


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FIG.13



United States Patent Office

3,007,823

Patented Nov. 7, 1961

3,007,823
METHOD AND APPARATUS FOR QUENCH HARDENING

Robert V. Adair and Oliver F. Bauer, Rochester, N.Y., assignors to The Gleason Works, Rochester, N.Y., a corporation of New York

Filed Jan. 24, 1958, Ser. No. 710,882
29 Claims. (Cl. 148—131)

The present invention relates to a method and apparatus for quench hardening ring gears and like parts.

In conventional quench hardening apparatus of this kind, the part is quenched while held clamped between dies which hold it against distortion. One serious difficulty has been that the quenched parts tend to be distorted in the way that a resilient disc is flexed by pressure applied to its center when its periphery is held. In the case of a ring gear the plane back face thereof may distort to either internal or external conical shape, the latter being more usual. Increase of the clamping pressure does not overcome this difficulty and in some cases even increases the amount of distortion. The present method and one aspect of the present apparatus is based upon the discovery that this distortion is substantially reduced by periodically releasing and then reapplying the clamping pressure as the quenching operation proceeds.

Other features of the new apparatus represent improvements on the machine disclosed in co-pending application Serial No. 554,857, filed December 22, 1955, by R. V. Adair and E. D. Dammert, now Patent No. 2,860,077.

The foregoing and other objects and advantages of the invention will appear from the following detailed description made with reference to the accompanying drawings, wherein:

FIG. 1 is a front view of the machine which constitutes the preferred embodiment of the apparatus;

FIG. 2 is a vertical sectional view through the supporting and actuating mechanism for the upper dies of the machine, a portion of the view being in the planes indicated by section line 2—2 of FIG. 4;

FIG. 3 is a detail sectional view in vertical plane 3—3 of FIG. 2;

FIG. 4 is a horizontal sectional view in plane 4—4 of FIG. 2;

FIG. 5 is a view in the horizontal planes indicated by section line 5—5 of FIG. 2;

FIGS. 6 and 7 are isometric views each showing one of the two positions of a locking device appearing in FIGS. 2 and 5;

FIG. 8 is a vertical sectional view, in the planes indicated by section line 8—8 in FIG. 9, through the lower die parts and their supporting and actuating mechanism;

FIG. 9 is a fragmentary plan view of parts shown in FIG. 8;

FIG. 10 is a detail side view illustrating an adjustable stop device included in the structure shown in FIG. 8;

FIG. 11 is a diagram illustrating the distortion of ring gears occurring during a quenching operation; and,

FIGS. 12 and 13 are diagrams respectively of the hydraulic system and of the electrical system of the machine.

The machine includes a base 21 comprising a quenching tank and three upright rods 22, 23 and 24 connected at their upper ends by a head 25. A press frame 26 is slidable on rods 22 and 23, such motion of the frame being effected by a motor 27 which through reduction gearing rotates two cranks 28 in unison. The cranks are journaled for rotation in the base about aligned horizontal axes 29 and their crank pins 31 are journaled in the upper ends of connecting rods 32. The lower ends of these rods journal crank pins 33 carried by the press frame 26. Journaled for rotation in the press frame

on horizontal axis 34 are two motor driven cranks 35 whose crank pins are journaled in the upper ends of connecting rods 36. The lower ends of the connecting rods are pivotally connected by crank pins 37, FIGS. 2 and 3, to a vertical slide 38 on rods 22 and 23. The slide is connected to an upper die carrier 39 by an adjusting screw 41. The arrangement is such that when the cranks 35 are rotated one-half turn from the position shown, about axis 34, the slide 38, screw 41 and die carrier 39 are lowered to close the upper dies upon a workpiece, in this case ring gear G, supported on lower dies on the press frame 26; and upon rotation of cranks 28 by one-half turn about axis 29, from the position shown, the press frame will be lowered to carry the workpiece below the level of quenching liquid in the tank. Upon a further half turn of cranks 35 about axis 34 the upper die carrier will be raised to release the workpiece, and upon a further half turn of the cranks 28 the press frame will be returned upwardly to the position shown.

Referring to FIGS. 2 and 4, the upper die carrier has a central cylinder chamber 42 aligned with screw 41. Slidable in the cylinder is a piston 43 whose rod 44 has a conical expander 45 for a multi-part, radially expansible centering device 46 adapted to fit in the central bore of the workpiece G. The centering device comprises a plurality of segments which are compressed radially by a ring-shaped coiled spring 47. The segments rest on a plate 48 carried by the rod 44.

Arranged in a circle around cylinder 42 are six cylinder chambers 48 in which pistons 49 are reciprocable. The rods 50 of these pistons are all connected at 51, at their lower ends, to an inner die assembly comprising an annular die member 52 that is adapted to bear upon the inner portion of the upper face of the workpiece, which is upon the flange of the gear G in the particular case illustrated. To prevent excessive heat from being conducted to the cylinder and piston assembly 50, 49, 39, 43, 58, an annular chamber 53 for coolant is provided in the die assembly, and suitable conduits not shown extend from this chamber to a coolant circulating system. Concentric with member 52 is the annular die member 54 of an outer die assembly having a coolant chamber 55 connected to the circulating system. Member 54 is adapted to bear on the outer portion of the upper face of the workpiece, in this case upon the top surfaces of the outer ends of the gear teeth. The outer die assembly is connected at 56 to the lower ends of six piston rods 57 whose pistons 58 are reciprocable in cylinder chambers 59 in the carrier 39. As shown the connections 51, 56 between the piston rods 50, 57 and the related die members 52, 54 are adapted to allow slight lateral movement of the latter so that they may slide freely relative to each other and to the tubular part 59' of carrier 39 which guides them. The device 46 is expanded by the application of hydraulic pressure to cylinder chamber 42 through port 61. Hydraulic pressure may be applied respectively to the upper ends of chambers 48 and 59 through ports 62 and 63 to press the die members 52 and 54 downwardly against the workpiece.

The upward reaction of such pressure is transmitted by the screw 41 to the slide 38 which in turn transmits it to the frame 26. The screw is secured to the die carrier 39 and is screw-threaded to a nut 64 rotatable in the slide. For adjusting the height of the carrier in the down position of the slide the nut is turned by means of an adjusting worm 65 which meshes with a worm wheel 66 integral with the nut. The means whereby the upward reaction is transmitted from the slide to the frame are duplicated on both sides of the machine, but only the means on the right side are shown, in FIGS. 2 and 5 to 7 inclusive. They include a plurality of tongues 67 provided on the slide and on hardened steel bars 68 secured to it.

These tongues are adapted to abut a stop 69 on frame 26 in the down limit position of the slide. Tongues 70 on the frame 26, and on a hardened steel bar 71 secured to it, are aligned with the spaces between tongues 67 so that the latter may pass by as the slide is raised or lowered. Slidable horizontally in the frame is a lock bar 72 having tongues 73 which in the locking position of the bar shown in FIG. 6 are aligned with the tongues 67 and 70 whereby they may transmit upward load from the slide 38 directly to the frame, and in the unlocking limit position of the bar, shown in FIG. 7, are misaligned from tongues 67 to permit vertical motion of the member 38.

For shifting the lock bar 72 between its locking and unlocking limit positions a piston 74 is connected to the bar by blocks 75. In these limit positions the respective blocks about related stops 76 on the frame. The piston is reciprocable in a cylinder 77 on the frame, reciprocation being effected by hydraulic pressure applied to the ends of the cylinder chamber through ports 78 and 79, FIG. 5.

To assure seating of bars 68 on stops 69 despite slight overtravel or undertravel of the cranks 35 relative to their intended bottom dead center positions as they lower the upper die carrier assembly, the stops 69 are positioned slightly higher than they theoretically should be in relation to the throw of the crank pins and the length of connecting rods 36. To accommodate this positional discrepancy and also to prevent the heavy hydraulically applied pressure against the workpiece from reacting against the crank and connecting rod means 35, 36, resilient means are associated with the connecting rods. For this purpose each connecting rod 36 has a slot 81 slidably receiving a block 82 which is urged downwardly relative to the rod by compression springs 83 backed by a slot bridging member 84. Plates 85 secured to the block hold it against lateral displacement. Confined between the bottom of the block and the rod is a roller bearing 86 which journals the connecting rod pin 37 secured to slide 38. The arrangement is such that when the carrier and slide assembly is urged upwardly by the reaction from the pressure applied to the workpiece, the springs 83 yield sufficiently to allow the tongues 67 of upper bar 68 to bear against the tongues 73 of the lock bar which in turn bear upon the tongues 70 of bar 71 and frame 26. Thus the crank and connecting rod structure does not bear this load and hence can be much lighter than would otherwise be possible.

Referring to FIG. 8, the base of press frame 26 carries an articulated die for supporting the workpiece. This die comprises concentric outer and inner annular members 87 and 88 supporting a plurality of radially disposed segmental bars 89 which are adapted to engage the plane bottom face of the workpiece. For holding the bars in place their end portions of reduced thickness are received in annular grooves in a ring 90 seated on the frame and in a ring 91 keyed to a tubular part 93; and the reduced ends of the bars are provided with recesses receiving positioning pins 92 carried by rings 90 and 91. Annular member 87 is seated on the frame while member 88 is supported by the part 93 which in turn is supported by a piston rod 94. To this rod are screw-threaded, by threads 95 of opposite hand, upper and lower piston sections 96 and 97. The piston is disposed in a cylinder chamber in a member 98 whose upper and lower ends are closed by heads 99 and 101. The parts 98, 99 and 101 are all secured to the frame.

The piston sections are held against rotation by keys 102 and 103, whereas the piston rod is rotatable by a wrench applied to its socket 104. By such rotation the piston sections may be adjusted toward or away from each other to thereby adjust the stroke of the piston between cylinder heads 99 and 101. In the limit position of adjustment shown in FIG. 8 this stroke is zero, but when the flexing feature is in use with automobile ring gear workpieces the stroke will ordinarily be in a range

of about twenty-to forty-thousandths of an inch. After a stroke adjustment is made the piston rod is locked to part 93 by means of nut 105 and set screw 106. Part 93 is held against rotation in the frame by a key 107 secured to cylinder head 99. When the adjustment is such that the piston has some stroke, the assembly including the piston, rod 94, and annular member 88, may be reciprocated by alternate application of hydraulic pressure through a passage 109 to the lower chamber of the cylinder 98 and through ports 62 to the cylinders 48. This rocks the bars 89 upon the annular member 87 which serves as a fulcrum, so that the workpiece is flexed in a way which causes its lower plane surface to alternately assume an external and an internal conical shape. This of course requires the exertion of a sufficient downward pressure to the annular die members 54 to hold the gear in full engagement with the bars 89. Springs 111 are arranged to act between the piston sections and the cylinder heads to eliminate backlash between the sections and the piston rod.

The above-described flexure is preferably concluded before quenching is begun, and during the quenching, or at least during a part thereof, the workpiece is held in one position by the dies. Whether it is held perfectly flat, or slightly dished either concavely or convexly, is determined by an auxiliary stop means which limits the downward motion of the assembly 96, 97, 94, 88 toward the cylinder head 101. This auxiliary stop means, FIGS. 8, 9, and 10, comprises a ring 112 rotatable around part 93 and resting on cylinder head 99. The ring has a plurality of inclined surfaces 113 in contact with complementary surfaces 114 on a ring 115 secured to part 93. Preferably these surfaces are of helicoidal or screw shape so as to have substantial contact area. By turning the ring 112 in one direction or the other the downward limit position of ring 115, and of the assembly 88, 93, 94, 96, 97 secured to it, is raised or lowered. Thus movement of 112 to the left in FIG. 10, to the broken line position, would allow further downward motion of ring 115 through the distance D.

The ring 112 is moved by a piston 116 whose rod 117 is pivotally connected at 118 to a pitman 119 which is pivoted at 121 to the ring. Such movement is effected by application of hydraulic pressure through port 122 or 123 to the opposite ends of the cylinder chamber 124 in which the piston is reciprocable. When the piston is in its limit position to the left, the auxiliary stop means 112, 115 are entirely ineffective, irrespective of the stroke adjustment of piston 96, 97. The limit position of the piston to the right, which determines the auxiliary stop position, is controlled by abutment of piston rod 117 with an eccentric 125. This eccentric is integral with a shaft 126 rotatable in the frame to adjust this limit position. Such adjustment may be made by means of a wrench applied to socket 127 after a clamp ring 128 held by screws 129 is first released. A calibrated plate 131 secured to shaft 126 shows the position of adjustment of the eccentric.

When the upper and lower dies are closed on the workpiece and the press frame is lowered into the quench tank, quenching liquid is circulated under pressure by a suitable pump, not shown, through a system including stationary pipes 132, FIG. 8, which in the lower position of the press frame extend through openings 133 in cylinder member 98. The pipes have openings 134 through which the fluid discharges tangentially into an annular chamber 135 in the frame. From this chamber it flows upwardly through openings 136 in the frame and aligned openings 137 in a ring 138 seated in an annular groove 139 in the frame. The rate of flow may be adjusted by rotating the ring in the groove, after which the ring is locked by a screw 141, FIG. 9. From the groove 139 some of the fluid, confined by shroud 142, FIG. 2, flows across the bottom face of the workpiece through grooves 143 in bars 89, FIGS. 8 and 9. Leakage

around the bars returns through passages 144 to the quench tank. The remainder of the liquid flows from groove 139 through the tooth spaces of the workpiece, the space between die members 54 and 52, openings 145 in member 52, chamber 146, and returns to the tank through openings 147.

The hydraulic system of the machine, diagrammed in FIG. 12, comprises a sump 148 located in base 21, a motor driven pump 149 receiving hydraulic fluid from the sump and discharging it into a high pressure line 151, and a return line 152 leading back to the sump. There are five solenoid operated reversing valves designated 153 to 156 and 158 and a solenoid operated selector valve 157, each of these valves being actuated by two solenoids, *a* and *b*. The lines 151 and 152 are connected by reversing valve 153 to the passages 78 and 79 which lead to opposite ends of cylinder 77; and are connected by reversing valve 154 to passages 122 and 123 leading into the opposite ends of cylinder 124. Selector valve 157 connects pressure line 151 either to line 159 or 161. The lines 151 and 152 are also connected by reversing valve 155 to lines 162 and 163 leading to the lower and upper ends respectively of a cylinder 164 for a valve-operating piston 165; and are connected by reversing valve 156 to lines 166 and 167 leading to the lower and upper ends of a cylinder 168 for valve-operated piston 169. Reversing valve 158 connects line 160, which joins line 161, either to passage 169 leading to the lower end of cylinder 98 or to line 171 leading to a selector valve 172 operated by piston 169.

The selector valve 173 operated by piston 165 connects either line 174 or line 175 to the passage 61 which leads into the operating cylinder 42, FIG. 2, of the centering device. Line 174 is a low pressure line, being connected to line 159 by a pressure reducing valve 176 which is adjusted for a pressure on the order of five pounds per square inch. Line 175 is a high pressure line, being connected to line 161 by a reducing valve 177 which is adjusted for a pressure in the range of twenty-five to two hundred fifty pounds per square inch. Lines 169 and 171 may also be subjected to high pressure, since a reducing valve 178 interposed in line 160 between line 161 and reversing valve 153 is adjusted for a pressure in the range of twenty-five to one thousand pounds per square inch. Another pressure reducing valve 179 adjusted for a high pressure of between twenty-five and one thousand pounds per square inch is interposed between line 161 and a line 181. Selector valve 172 operated by piston 169 connects either low pressure line 174 or high pressure line 171 to passage 62 into cylinders 48 for the inner die member 52. Another selector valve 182 operated by piston 169 alternately connects low pressure line 174 and high pressure line 181 to passage 63 leading into cylinders 59 for the outer die member 54.

Referring primarily to FIG. 13, the electrical system of the machine includes start and stop switches 183 and 184 for a controller 1M for the motor for circulating quenching liquid, the controller when energized closing holding contacts 1M–1; and start and stop switches 185 and 186 for a controller 2M for the motor for hydraulic pump 149, this controller having holding contacts 2M–1. Momentary closing of switches 183 and 185 will connect the controllers across power leads L–1 and L–2 and thus cause their motors to run. It will also connect lead L–1 to wire 187. The system includes a two-position push button quenching cycle start switch 188; a controller 3M for the motor which drives cranks 35 to raise and lower the die carrier 39, this controller when energized closing holding contacts 3M–1; and a controller 4M for the motor 27 which raises and lowers the press frame 26.

For effecting the flexing of the workpiece there is a cam 189 operated through speed reduction gearing by a small variable speed motor 5M, whose speed control circuit is not shown. The cam comprises a pair of plates which are angularly adjustable to vary the effective length of its lobe. As the cam rotates it causes a snap-action switch arm 190 to alternately close against contacts 191 and 192. For effecting the alternate application and release of pressure to the dies, referred to as "pulsing," a similarly adjustable cam 193 is operated through speed reduction gearing by a small variable speed motor 6M, the cam causing a switch 194 to alternately open and close.

A counter for the number of flexures is provided. It comprises a reset coil 1C which when energized closes four sets of contacts 1C–1 to 1C–4 and opens five sets of contacts 1C–5 to 1C–9. It further comprises a coil 2C which is energized momentarily upon each flexure, and at the conclusion of a number of energizations, which is adjustable, it causes contacts 1C–1 to 1C–4 to open and contacts 1C–5 to 1C–9 to close. A similar adjustable counter for the number of pulsing cycles comprises a reset coil 3C which when energized closes five sets of contacts 3C–1 to 3C–5 and opens two sets of contacts 3C–6 and 3C–7; and a coil 4C momentarily energized upon each pulsing cycle and which, upon being energized the number of times for which the counter is set, opens contacts 3C–1 to 3C–5 and closes contacts 3C–6 and 3C–7.

The system also includes an automatic cycle control relay 1R having five sets of contacts 1R–1 to 1R–5 which are closed only when the relay is energized; a relay 2R, which stops the press frame in up position, and having four sets of contacts 2R–1 to 2R–4 closed only when the relay is energized and contacts 2R–5 closed only when the relay is deenergized; and a relay 3R, which stops the press frame in down position, comprising contacts 3R–1 to 3R–3 closed only when the relay is energized. A lock control relay 4R has contacts 4R–1 and 4R–2 which are closed and contacts 4R–3 which are opened only when the relay is energized. There is also a valve control relay 5R having contacts 5R–1 to 5R–3 which are closed, and contacts 5R–4 to 5R–6 which are opened, only when the relay is energized; a flexing control relay 6R having contacts 6R–1 and 6R–2 which are respectively closed and open only when the relay is energized; and another valve control relay 7R whose contacts 7R–1 and 7R–2 are closed only when the relay is energized and whose contacts 7R–3 and 7R–4 are open only when it is deenergized.

The electrical system further includes a manually operable switch 195 which when opened eliminates flexing; a manually operable switch 196 which may be opened to eliminate the pulsing operation; and machine operated limit switches designated S–1 to S–8. Switch S–1 closes its upper contact *a* only when the slide 38 is in its uppermost position in frame 26, and at all other times closes its contact *b*; and switch S–2 normally closes its contact *b*, shifting to close contact *a* only when the slide reaches its lowermost position in the frame. Switches S–3 and S–4 are normally open and are respectively closed only when the lock bars 72 on the right and left sides of the machine are in unlocking position as in FIG. 7. Switches S–5 and S–6, also normally open, are closed only when the respective right and left lock bars are in locking position, as in FIG. 6. As indicated in FIGS. 2 and 5, switches S–3 and S–5 are contained in a single switch housing and are operated by the same switch lever 180. The same is true of switches S–4 and S–6. Switches S–7 and S–8 are normally closed and are respectively opened only momentarily when the press frame reaches its upper and lower limit positions relative to the base 21.

Operation

The machine will end its quenching cycle with both the press frame and the die carrier 39 in their upper positions. Assuming that the switches 183 and 185 have previously been closed, the quench liquid pump and the hydraulic pump are operating, and lead 187 is connected to lead L–1 so that solenoids 153*b*, 154*a*, 155*a*, 156*a*,

157*b*, and 158*a* are energized. Accordingly the lock bar 72 is in unlocking position, the auxiliary stop 112 is in stop position, valve 173 causes low pressure to be applied to centering device 46, valves 172 and 182 apply low pressure to the inner and outer die members 52 and 54, and valve 157 connects line 159 to pressure line 151. Valve 158 is ineffective since line 161 is disconnected.

To operate the machine through a normal cycle a hot workpiece G is placed on die bars 89 and switch 188 is momentarily depressed to position 188'. This momentarily energizes relay 1R, which results in energization of counter reset coil 1C (assuming switch 195 is closed), counter reset coil 3C, relay 2R and relay 3R. Relay contacts 2R–4 and 2R–5 are respectively closed and opened, operating valve 157 to connect line 161 to pressure line 151; counter contacts 1C–3 and 1C–8 are respectively closed and opened, operating valve 155 to apply high pressure to centering device 46; and counter contacts 1C–4 and 1C–9 are respectively closed and opened to reverse valve 154 to retract auxiliary stop 112. The motor controller 3M is energized, to cause the upper die carrier 39 to be lowered by cranks 35, by a circuit established through contact *b* of switch S–2 and relay contacts 3C–2 and 1R–3, the circuit being held after deenergization of relay 1R by contacts 3M–1.

When the die carrier 39 reaches its lower limit position switch arm S–2 closes against its contact *a*, thereby deenergizing controller 3M and stopping rotation of cranks 35 and energizing relay 4R with the result that contacts 4R–2 and 4R–3 respectively close and open to reverse valve 153, causing the lock bars 72 to be shifted to locking position. As this is accomplished switches S–3 and S–4 open and limit switches S–5 and S–6 close, energizing relay 5R and flexing motor 5M. Contacts 5R–3 and 5R–6 respectively close and open to cause reversal of valve 156 which in turn causes shifting of valves 172 and 182 to apply high pressure to the upper outer die member 54, so that the outer peripheral portion of the workpiece is clamped, and the cylinders 48 of the upper inner die member are connected to line 171. At the same time the contacts 5R–2 and 5R–5 are respectively closed and opened to energize solenoid 155*a* and deenergize solenoid 155*b* to thereby reverse valve 155, and in turn valve 173, so that the centering device 46 is subjected to the lower pressure of line 174. As the motor 5M rotates cam 189 to alternately energize relay 6R by closing and opening switch arm and contact 190, 192, the relay contacts 6R–1 and 6R–2 are thereby alternately closed and opened to cause reversal of valve 158. This alternately applies downward pressure against the upper inner die member 52 and, through piston 97, 96, upward pressure against the lower inner annular member 88, thereby flexing the workpiece at a frequency which depends upon the speed for which the motor is adjusted. This is preferably within a range of about twenty to one hundred twenty workpiece flexures per minute for automobile ring gears of various sizes.

On each flexure the counter coil 2C is energized and upon reaching the number of energizations for which the counter is set, which ordinarily will be in the range of one to ten, the counter contacts 1C–1 to 1C–4 open, and contacts 1C–5 to 1C–9 close. This occurs while upward pressure is being applied to annular member 88. Opening of 1C–1 deenergizes counter reset coil 1C. Opening of 1C–4 and closing of 1C–9 reverses valve 154 so that the auxiliary stop ring 112 is moved into its stop position. Although contacts 1C–2 are now open the motor 5M continues to operate, as a result of closing of 1C–5, until cam 189 causes switch arm 190 to snap away from contact 192 and against contact 191. This causes the last reversal of valve 158 so that pressure is applied to upper die member 52, flexing the inner peripheral portion of the workpiece downwardly as far as is permitted by the auxiliary stop 112.

Closing of contacts 1C–6 establishes a circuit through controller 4M for motor 27 which operates to lower the press frame into the quench tank, the motor stopping when limit switch S–7 opens and thereby deenergizes relay 3R so that contacts 3R–2 open. Quenching fluid from pipes 132, FIG. 8, now circulates over the workpiece in the paths previously described. Closing of contacts 1C–6 also energizes pulsing motor 6M, causing alternate energization and deenergization of relay 7R and counter coil 4C by cam operated switch 194. The resulting alternate closing and opening of contacts 7R–2 and 7R–4 periodically reverses valve 156 which in turn causes reversal of valves 172 and 182. Similarly the alternate closing and opening of contacts 7R–1 and 7R–3 reverses valve 155 which in turn causes reversal of valve 173. Thus periodically the high pressure exerted by the die members 52 and 54 and the centering device 46 is released and re-applied as the quenching operation proceeds. The frequency of this pulsing is dependent upon the speed for which the motor 6M has been adjusted. For automotive ring gears it is preferably within a range of twenty to two hundred pulses per minute. At the conclusion of the number of energizations of coil 4C for which the pulsing counter has been set, the contacts 3C–1 to 3C–5 open and contacts 3C–6 and 3C–7 close. Usually the number will be set such that the pulsing will extend over the desired period, which for automobile ring gears will be about ten to fifteen seconds. Upon opening of contacts 3C–4 the relay 5R is deenergized, and its contacts 5R–6 and 5R–4 closed, so that low pressure only is applied to die members 52 and 54 and to the centering device 46.

Since contacts 3R–1 are now open, the opening of 3C–3 results in deenergization of relay 4R, this causing reversal of valve 153 and shifting of lock bars 72 to unlocking position. This opens switches S–5 and S–6, and closes switches S–3 and S–4, causing energization of motor controller 3M through the circuit including contact *b* of switch S–1 and contacts 3C–6. The upper die carrier assembly 38, 39 will therefore be raised. Preferably there are suitable work handling means, not shown and forming no part of the present invention, to remove the workpiece from the lower dies for further cooling in the quench tank. When the slide 38 reaches its uppermost position switch S–1 will be opened from its contact *b* and closed against its contact *a*, deenergizing the controller 3M and establishing a circuit through switch 188, contacts 1C–7 and controller 4M of motor 27. As a result the press frame will be raised to its upper limit position in which switch S–3 is opened. This deenergizes relay 2R, reestablishing the conditions that existed prior to depression of the quenching cycle start button 188. Thus the machine is ready to repeat the quenching cycle when another workpiece is placed on the lower die bars 89.

With the switch 195 opened the machine operates through the same cycle described above except that the flexing of the workpiece prior to quenching is omitted. The counter reset coil 1C is not energized and accordingly contacts 1C–2 remain open so that motor 5M does not operate. Consequently as soon as the upper die carrier 39 reaches its lower limit position and the locking bars 72 are shifted to their locking position, closing switches S–5 and S–6, the controller 4M of motor 27 is energized through a circuit from lead 187 to lead L–2 through switches S–5 and S–6, switch arm and contact 190, 191, and contacts 1C–6 and 3R–2. Thus the motor 27 is operated to lower the press frame 26 and the cycle continues on as described before.

With the switch 196 opened the machine also operates through the same complete cycle previously described except that pulsing is omitted. The pulsing motor 6M and the pulse counter comprising coils 3C and 4C operate as before to determine the length of the quenching phase of the cycle, but the relay 7R is not energized so that the contacts 7R–1 and 7R–2 remain open and con-

tacts 7R–3 and 7R–4 remain closed, with the result that valves 155 and 156 are not reversed to cause pulsing. Solenoids 155b and 156b remain energized, so that valves 155 and 156 maintain pressure in lines 163 and 167, with the result that valves 173, 172 and 182 direct high pressures into the cylinder 42 for centering device 46 and into the cylinders 43 and 59 for inner die members 52 and 54 throughout the quenching cycle.

In FIG. 11 is shown a ring gear G being quenched while held clamped to a lower die 89 by upper die members 52 and 54 and held centered by a centering device 46. Without the pulsing of the present invention gears frequently distort in the sense of dishing upwardly as shown, greatly exaggerated, by the dash-dot outline of the gear. One theory is that such distortion occurs because as the gear cools, and hence attempts to shrink with resulting displacement of the center of mass 197 in the inward radial direction indicated by arrow 198, it is held against such contraction by the clamping pressure at 199 and 201 on the flange of the gear whose center is at 202. As a result the center 197 can move in direction 198 only by rotation about point 202, producing the distortion in direction 203. In other cases, where the point at which the workpiece is held is located above its center of mass 197, the dishing distortion has been observed to be in the opposite direction, to impart a concave shape to the originally plane bottom surface of the workpiece. When the pulsing is used the clamping pressure is periodically released, allowing the shrinking gear to readjust itself between the dies, with the result that the forces acting to produce the dishing distortion are released. The clamping of the workpiece between the dies, before and after each release of pressure, is sufficient to hold the gear against other kinds of distortion. It will be understood that the foregoing explanation is a theory only, and that there may be other factors, not presently understood, which account for the dishing distortion effect. Whatever the complete explanation, it has been found that the pulsing action described herein greatly improves the quality of the quenching workpieces by either eliminating or by greatly reducing the magnitude of the dishing effect.

In the illustrated apparatus the workpiece rests on the bars 89 rather than on the annular members 87 and 88, this arrangement being preferred because it presents a contact area extending across the full width of the bottom face of the workpiece. However, in some cases the bars may be omitted and the members 87, 88 made of suitable greater height to directly engage the bottom of the workpiece. Thus the members 87 and 88 may be regarded as themselves being the lower die members and the bars 89 as being merely filler or pressure distributing parts interposed between the dies and the workpiece. In some cases, where the shape of the workpiece permits, pressure distributing parts similar to bars 89 may be associated with the upper die assembly 52, 54. It will be understood that the foregoing and various other changes may be made in the apparatus without departing from the spirit of the invention or from the scope of the appended claims.

Having now described the improved method and apparatus, what is claimed as our invention is:

1. The method of quench hardening a ring gear or like part, in which a quenching medium is applied to the heated part while it is held between clamping dies, the improvement comprising periodically releasing the clamping pressure exerted on the part by the dies as the part is being cooled by said medium, to thereby enable the part to periodically shift relative to the dies in response to its thermal contraction.

2. The method of quench hardening a ring gear or like part, in which a liquid quenching medium is applied to the heated part while it is held between clamping dies, the improvement comprising releasing and reapplying the clamping pressure exerted on the part by the dies as the part is being cooled by said medium, to thereby allow the part to shift relative to the dies in response to its thermal contraction.

3. The method of quench hardening a ring gear or like part, in which a liquid quenching medium is applied to the heated part while it is held clamped between dies, such application of quenching medium being subsequent to any flexing of the part by relative motion between parts of the dies, the improvement comprising releasing and reapplying the clamping pressure exerted on the part by the dies as the part is being cooled by said medium, to thereby allow the part to shift relative to the dies in response to its thermal contraction.

4. The process of treating a ring gear or like part which comprises flexing the part while hot by relative movement of die members between which the part is clamped, then applying a liquid quenching medium to the part while it is being held clamped by the dies, and during the course of such quenching releasing and reapplying the clamping pressure exerted on the part by the dies as the part is cooled to thereby allow the part to shift relative to the dies in response to its thermal contraction.

5. Apparatus for quench hardening a ring gear or like part, comprising a pair of dies between which the part may be clamped while being quenched, a system for effecting flow of a quenching medium over the part while the latter is so clamped, means for applying clamping pressure to the dies, and coordinated control means for said system and said pressure applying means, said control means being operable to cause release and reapplication of clamping pressure to occur during and in predetermined time relation to the period of quenching flow, while the part is undergoing thermal contraction.

6. Apparatus according to claim 5 in which the means for applying clamping pressure is operated by hydraulic pressure and said control means include valve means actuated periodically to reduce the pressure applied to the part.

7. Apparatus according to claim 6 in which there is a motor and a cam driven thereby which is arranged to actuate said valve means for effecting the periodic reduction in pressure, said motor being of the variable speed type whereby the frequency of said pressure reductions may be varied.

8. Apparatus for quench hardening a ring gear or like part, comprising two sets of concentric members through which pressure may be applied against the opposite faces of the part, means for applying pressure to a member of one set for clamping the part between the member and the opposing member of the other set, separate hydraulically operated means for respectively applying pressure against the other members of said sets, and means for reversingly applying differential pressures to said separate hydraulically operated means to thereby flex the part back and forth.

9. Apparatus according to claim 8 in which there is a means to adjust the stroke of one member of said other members resulting from reversals of the pressure differential.

10. Apparatus according to claim 9 in which the hydraulically operated means comprises a piston and a piston rod connecting the piston to said one member, and the stroke adjusting means comprises two sections of the piston having screw-threaded connections of opposite hand to the piston rod and means whereby the rod may be rotated relative to said sections to thereby adjust the effective length of the piston.

11. Apparatus according to claim 8 in which the means for reversing the pressure differential comprises a motor and a cam driven thereby, and valve means operated by the cam, the motor being of the variable speed type whereby the frequency of flexure of the part may be varied.

12. Apparatus according to claim 8 in which the stroke of one member of said other members is limited, and

there is an auxiliary stop movable to and from a position in which it further restricts the stroke of said one member away from its opposing member.

13. Apparatus according to claim 12 in which there is an actuator for said movable stop, and means effective after a predetermined number of flexures of the part to cause the actuator to shift the stop to said position and to discontinue said reversing of the pressure differential while the latter is in a direction to hold said one member against the stop.

14. Apparatus according to claim 12 in which there is an adjusting means for varying said position of the auxiliary stop.

15. Apparatus according to claim 14 in which said auxiliary stop comprises a rotatable ring having a plurality of inclined surfaces engaging similarly inclined surfaces on a part rigid with said one member, and said adjusting means comprises an adjustable stop to limit the rotation of the ring in one direction.

16. Apparatus for quench hardening a ring gear or like part having a supporting structure for such part comprising a pair of concentric annular members which are adapted for relative motion in the direction of their axis, a plurality of bars for contacting a face of the part, said bars being substantially radial of said axis and being supported by said members for rocking action thereon upon such relative motion of the members.

17. Apparatus for quench hardening a ring gear or like part having a supporting structure for such part comprising a pair of coaxial outer and inner annular members, means for effecting relative adjustment between said members in the direction of their axis, a plurality of bars for contacting a face of the part, said bars being substantially radial of said axis and being supported by said members for rocking action thereon upon such adjustment.

18. Apparatus for quench hardening a ring gear or like part, comprising a pair of concentric annular die members for engaging a face of the part, a die carrier having two sets of cylinders parallel to the axis of said die members, there being a plurality of cylinders in each set, pistons reciprocable in the cylinders, and the pistons in the cylinders of one set being connected to one die member and those in the other set being connected to the other die member.

19. Apparatus according to claim 18 in which said two sets of cylinders are arranged in concentric circles about said axis and said carrier has another cylinder aligned with said axis, a piston in said cylinder, and a workpiece centering device carried by said piston.

20. Apparatus for quench hardening a ring gear or like part, comprising a press frame adapted to support a lower die, a carrier for an upper die slidable vertically on the frame, means for raising and lowering the carrier relative to the frame, means for exerting clamping pressure between the upper and lower dies after the carrier has been lowered whereby upward force is applied to the carrier, and means for locking the carrier to the frame against upward motion from its lower position prior to application of such clamping pressures.

21. Apparatus according to claim 20 in which the locking means comprises tongues on the frame, tongues on a part secured to the carrier, the latter tongues being so aligned with the inter-tongue spaces on the frame that they will pass through them as the carrier is raised and lowered, and a lock bar horizontally slidable on the frame and having tongues so disposed that in one position of the bar they may abut the tongues of both said part and the frame, and that in another position of the bar they are so aligned with the inter-tongue space of said part that the latter part may pass them.

22. Apparatus according to claim 20 in which the carrier is resiliently connected to said means for raising and lowering the carrier.

23. Apparatus according to claim 20 having a slide movable vertically on the frame, and means for connecting the carrier and for adjusting it vertically with respect to the slide, the means for raising and lowering the carrier relative to the frame being effective between the frame and the slide, and the locking means also being effective between the frame and the slide.

24. Apparatus according to claim 22 in which the raising and lowering means comprise a pair of cranks rotatable on the frame and said resilient connection comprises two connecting rods respectively conecting the cranks to the carrier, each rod having two parts connected to each other for limited relative sliding motion to thereby change the effective length of the rod, and resilient means acting between said parts to yieldably hold them in one limit position relative to each other.

25. Apparatus for quench hardening a ring gear or like part, comprising dies between which the part may be confined while being quenched, a quenching system for applying a fluid quenching medium to the part while it is between said dies, means for exerting pressure on the dies for clamping the part between them, and a control system for said quenching system and for applying and releasing said pressure exerting means, said control system comprising means for causing the release and reapplication of said pressure exerting means to occur during and in predetermined time relationship to the quenching of the part by the quenching system, to thereby enable the part to shift relative to the dies in response to its thermal contraction resulting from such quenching.

26. Apparatus according to claim 25 in which said control system includes an adjustable means for controlling the time interval between the initiation of quenching of the part by the quenching system and said releasing of the pressure exerting means during the course of quenching.

27. Apparatus according to claim 25 in which said control system includes means to effect repeated release and reapplication of pressure on the dies during the course of quenching of the part.

28. Apparatus according to claim 27 in which said control system includes a means which is adjustable to change the frequency of such repetitions.

29. Apparatus according to claim 27 in which said control system includes a means which is adjustable to change the number of such repetitions occurring during the course of said quenching of the part.

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