APPARATUS FOR HEATING AND QUENCHING METAL PARTS

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Application September 9, 1952, Serial No. 308,675

7 Claims. (Cl. 266—4)

This invention relates to improved apparatus and methods for hardening metal parts. The invention is particularly concerned with the hardening of parts which include sections of relatively thick wall thicknesses and adjacent sections having a very thin wall. The invention is also concerned with the heating and hardening of a metal part having substantial differences in the cross section of the part at different stations along its length.

One problem presented by workpieces, having substantial differences in wall thickness at different sections, is that the regions of different thickness do not heat evenly and great care must be exercised in order to have all parts of the workpiece pass through the decarburization point at substantially the same time. Another problem is concerned with the quenching of the workpiece, and even though the piece is heated so as to obtain substantially uniform temperature throughout, the sections of different wall thickness cool at different rates, and the quench is not uniform unless the temperature of the thick and thin wall sections can be maintained substantially the same up until the time of the quench.

It is an object of this invention to provide improved apparatus and methods for heating and quenching metal workpieces, and particularly metal workpieces having substantial variations in wall thickness, and substantial variations in the width of the workpiece at different regions along its length. In accordance with one feature of the invention, heat is applied differentially to the workpiece at different levels in a heating furnace and at a rate which compensates for variations in thicknesses of the workpiece. Another feature of the method relates to the quenching of the workpiece by lowering it into a quenching bath located immediately below the heating chamber of the furnace.

The apparatus includes a furnace having heaters located at different levels and with different numbers of heaters at the different levels for supplying different amounts of heat at regions corresponding to the uniform thickness and width of a workpiece in the furnace. Another feature of the apparatus relates to control of the fuel gas used by the heater so as to provide an auxiliary control of the heat in addition to the differences in the number of heaters located at the different levels of the furnace.

Still another object is to provide apparatus for moving the workpiece with respect to heaters in such a way as to obtain substantially uniform heating, and the apparatus also includes mechanism for moving the workpiece promptly and directly from the heating chamber of the furnace to the quenching pit located immediately below the heating chamber. Other features relate to the closing of the upper and lower ends of the heating chamber, especially to the partitioning off of the heating chamber from the quenching pit below it; also to the supporting means for the workpiece with provision for controlling the surging of the quenching fluid up into the workpiece and the resulting splashing of the quenching fluid into the heating chamber of the furnace.

Other objects, features and advantages of the invention will appear or be pointed out as the specification proceeds.

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views,

Figure 1 is a side elevation, partly broken away and in section, showing a heating furnace embodying this invention;

Figure 2 is a diagrammatic view showing a section through the heating furnace and illustrating the principle of operation of the apparatus;

Figure 3 is a fragmentary sectional view taken on the line 2—3 of Fig. 1;

Figure 4 is a fragmentary sectional view taken on the line 4—4 of Fig. 1;

Figure 5 is an enlarged, fragmentary, detailed view, partly in section, showing a part of the thrust bearing and one section of the cover that closes the top of the furnace;

Figure 6 is a side view, partly broken away, through one section of the bottom or partition that closes the lower end of the furnace when the furnace is in operation;

Figure 7 is an enlarged, detail view, partly in section, showing the support for holding the workpiece; and

Figures 8 and 9 are views taken on the lines 8—8 and 9—9 of Figure 7.

The shell of the furnace is lined with fire brick and there are heaters comprising gas burners embedded in the lining of the furnace. These burners are preferably of the type in which all or a substantial part of the combustion of a gas and air mixture takes place within the burner to heat the face of the burner to an incandescent radian. Discharge orifices in the face of the burner provide for the flow of the products of combustion from within the burner, and these hot products of combustion supplement the radiant heating of the incandescent burner faces. Such burners are well known in the art. The gas burners are, however, representative of heaters, and may be replaced with other kinds, but preferably with heaters in which a substantial part of the heat is discharged as radiant heat.

In the furnace illustrated, there are burners at sixteen different levels between the top and bottom of the furnace. At the top level, indicated by the reference line 21, there are two burners 18 at opposite sides of the furnace, as illustrated diagrammatically by the short radial lines on the circle 21'. This circle 21' represents a horizontal section through the furnace at the level 21.

At the next level 22 of the furnace there are two burners 18 represented by the short radial lines on the circumference of the circle 22'. It will be noted that the burners 18, at the level 22, are opposite one another but at a 90° phase difference from the burners 18 at the level 21 immediately above. At the next level 23 there are burners at the same location as at the level 21, as indicated by the radial lines on the circle 23'.

At the next lower level 24 there are four burners as indicated by the short lines on the circle 24'. These burners at the level 24 are spaced 90° apart and are at a phase angle of 45° from the burners at the level 23 immediately above. At the next lower level there are eight burners at uniform angular spacing around the circle 25'.

Below the level 25 there is a short length of furnace without any burners, and then there are a number of lower levels 26—35 with only one burner at each level, the burners being alternately on one side and then the other of the circles 26—35', which represent the cross section of the furnace at these different levels.

At the bottom of the furnace, at the level 36, there are eight burners at uniform angular spacing around the vertical axis of the heating chamber of the furnace. Be-
low the level 36 there is a water jacket 38 extending around the bottom rim 15 and forming with the bottom rim a cooling chamber for retarding heat flow downward through the metal shell of the furnace to the bottom of the furnace and the quenching pit below the furnace bottom.

Water flows into the water jacket 38 through the inlet pipe 41 and flows out of the water jacket through an outlet pipe 42.

A mixture of fuel gas and air is supplied to the burners 18 at the level 21 through pipes 43, on opposite sides of the furnace, connected with a manifold 44. This manifold 44 extends approximately one-half way around the shell 12 of the furnace and the manifold is spaced from the shell so as to protect it from the heat. The manifold 44 is closed at one end, and is connected at its other end to a vertical supply manifold 46.

The burners 18 at the level 22 are supplied with an air-gas mixture through pipes 48 leading from a manifold 49 which is also connected with the vertical supply manifold 46.

The vertical supply manifold 46 also supplies an air-gas mixture to another horizontal manifold 51, similar to the manifold 44 for supplying an air-gas mixture to the burners 18 at the level 23.

The four burners at the level 24 are supplied with gas through pipes 53 from a substantially annular manifold 54. The eight burners at the level 25 are supplied with gas from a substantially annular manifold 56 through relatively long pipes 58.

All of the burners at the levels 26-35 are supplied with gas through pipes 60 leading from a vertical manifold 61, and the eight burners at the bottom level 36 are supplied with an air-gas mixture through pipes 64 leading downward from a horizontal manifold 66.

The purpose of this rather elaborate arrangement of manifolds and branch pipes is to make possible the control of the individual burners as well as a control of groups of burners at different combinations of levels in the furnace. For the individual control of the burners a valve 68 is located in each pipe connection between every individual burner and the manifold from which it receives its supply of gas and air. All of these valves are indicated by the same reference character 68. Since all of the burners at the levels 21, 22, 23 and 24 receive their air-fuel mixture from the manifold 54, the fuel supply and the heat output of this entire group of burners can be controlled by regulating the pressure of the gas mixture to the manifold 54 and the resulting flow of air-gas mixture to the burners. This is done by means of a valve 70.

The gas supply and heat output of the eight burners at the level 25 is controlled by regulating a valve 72 which controls the gas supply and pressure in the manifold 56. In like manner the gas supply and heat output of all of the burners at the levels 26-35 are controlled by regulating a valve 74 which controls the gas supply to the manifold 61 and the resulting pressure in that manifold; and the heat output of the eight burners at level 36 is similarly controlled by a valve 75 which commands the gas supply pipe to the manifold 66.

There are inspection holes 77 opening through the wall of the furnace at regions adjacent to each of the burners. Most of these inspection holes are closed by manually inserted plugs when the furnace is in operation. These holes 77 are used for inserting a torch to light the respective burners and some of them are left open during operation for the insertion of pyrometers or other temperature-indicating instruments at different levels of the furnace where the temperature is to be determined. In the operation of the apparatus the air-gas supply is regulated by manifold valves 70, 72, 74 and 75 to bring different levels of the furnace to substantially the same temperature.

The furnace 10 is supported by gusset plates 80 welded to the side of the shell 16 and extending radially outward to supporting plates 81 which are secured to beams 82, preferably by welding. These beams 82 extend to the main frame 11, and the main frame rests on a floor 84 surrounding a quenching pit 85. The pit 85 contains quenching oil which is held in a pan 86 located directly under the heating chamber of the furnace so that workpieces from the heating chamber can be lowered directly into the oil in the quenching pit without leaving time for the different parts of the workpiece to cool unevenly.

When the furnace is in operation there is a partition separating the heating chamber of the furnace from the quenching pit 85. This partition, or furnace bottom 88 comprises two doors 89 supported by wheels 91 that run on a track 92.

The doors 89 are moved toward and from one another along the track 92 by fluid-actuated motors 94 connected to the doors 89 by piston rods 95. There is a separate motor 94 for each of the doors 89 and each of the doors 89 has a bumper 97 which comes into contact with an abutment 98 to stop the door when it has traveled one-half way across the lower end of the furnace. When both of the doors 89 have their bumpers against the abutment 98 the confronting faces of the doors are in substantial contact with one another so that they provide a bottom across the entire lower end of the heating chamber and completely partition off the heating chamber from the quenching pit 85 below it.

The workpiece 108 has a cover 109 comprising doors 102 which are somewhat similar to the doors 89. These cover doors 102 have wheels 103 which run on a track 104 provided by beams at the top of the frame 11.

Figure 2 is a diagrammatic view showing the way in which a workpiece 108 is supported within the furnace 10.

The workpiece 108 rests on a flange 110 which is carried by a support 111. There is another flange 112 located at a lower level of the support 111, and these flanges co-operate to maintain the workpiece with its longitudinal axis substantially co-incident with the vertical axis of the furnace. This construction for holding the workpiece will be described more fully in connection with Figures 7-9.

The workpiece 108 has an upper end 114 with a substantial wall thickness and an intermediate section 115 that has a much thinner wall, for example, one-fifth of the wall thickness of the upper section 114. At the lower end of the workpiece 108 there is another section 116 of substantially greater thickness than the intermediate shell section 115.

The upper section 114 of the workpiece is opposite the upper burners from the levels 21 to 25 (Figure 1) and the larger number of burners at the level 25 compensate for the smaller diameter of the workpiece at that level. This reduces diameter spaces the surface of the workpiece further from the incandescent faces of the burners with resulting decrease in the intensity of the heat radiating from each of these burners to the workpiece.

The thin wall portion 115 of the workpiece 108 is opposite the single burners at the levels 26-35 of the furnace, and the lower portion 116 of the workpiece is located in the region close to or immediately above the level 36 of the furnace.

In order to obtain uniform heating around the circumference of the workpiece 108, the support 111 is rotated at a fairly slow and uniform rate. The rotation is imparted to the support 111 by a bevel gear 113 which is preferably secured to the support 111 by a pin 121. This gear 120 is driven by a smaller pinion 122 on a shaft 123 which is rotated by a motor 124 through reduction gearing 125. The gear 122 has a longitudinally grooved hub 127 which slides on splines 128 of the shaft 123 so that the gear 122 can be moved out of the path of the bevel gear 120 when the support 112 and bevel gear 120 are to be raised, and during the time that they are being lowered into the position shown in Fig. 2.

The weight of the support 111 and the workpiece 108...
is carried by a thrust bearing 130, the construction of which will be explained more fully in connection with Figure 5. A hook 132 extends through an eye 133 at the upper end of the support 111. This hook is connected with a cable 138 by a swivel 136 so that the hook can rotate with the support 111 without turning the cable 135.  
The cable 135 extends upward over a pulley 138 supported by a carriage 139. This carriage has wheels 141 which run on an arcuate track 142 attached to the roof of the building or some other overhead structure. For the pulley 138 the cable 135 runs to another pulley 144 carried by a bracket 145 which is supported by a swivel 146 from the roof or other overhead structure. The bracket 145 is connected with the carriage 139 by a beam 147, in the illustrated construction.

The cable 135 extends downwardly, from the pulley 144, to a winch 148. The swivel 146 is in substantial alignment with the downwardly extending run of the cable 135 and the axis of the swivel 146 is preferably coincident with the center of curvature of the arcuate track 142. Thus, without causing any longitudinal movement of the cable 135, the carriage 139 can be moved along the track 142 to move the workpiece 168 over to a location outside of the furnace where the workpiece can be lowered to the floor or to a conveyor and another workpiece connected to the support 111 for hoisting to a level higher than the furnace. The carriage 139 is then moved back along the track 142 to locate the new workpiece 168 centrally above the furnace for lowering into the furnace.

The winch 148 has a drum on which the cable winds and there is a brake drum 149 at one end of the cable drum. A hand-operated, band brake 149a surrounds the brake drum 149.  
The inside of the brake drum 149 is formed with gear teeth; and there is a spur gear 149b which meshes with this internal gear to drive the cable drum with a speed reduction. The spur gear 149b is on a shaft driven through a chain and sprocket connection 150 from the power output shaft of a speed reducer 151. The speed reducer 151 is driven from an electric motor 152 through a clutch 153.

By providing control handles for the brake 149a and the clutch 153, the raising and lowering of the work support 111 can be accurately controlled. The winch 148 and its operating mechanism are merely representative of means for winding up or letting out various lengths of the cable for raising and lowering the workpiece.

Figures 3-6 show details of construction of the furnace. Figure 3 shows the way in which the furnace is supported by the gussets 80 resting on the supporting plates 81 which are welded to the beams 82 attached to the main frame 11. Figure 3 also shows the way in which the manifold 66 extends around the circumference of the furnace 10 to supply an air-gas mixture to the burners at different angularly spaced regions about the circumference of the furnace. This figure also shows the circular extent of the heating chamber of the furnace.

Figure 4 shows a section through the furnace at the level 22 with the manifold 49 for supplying an air-fuel mixture to burners on opposite sides of the heating chamber 151.

Figure 5 shows the construction of one of the doors 102. This door has metal sides 154 connected to a metal top plate 155. A layer of heat-insulating material 156 is below the metal plate 155; and there is a fire brick lining 157 held against the inside of the insulation 156 by supports 159 that extend into undercut slots 160 in the bricks of the lining.

The wheels 103 of the top doors 102 rotate on axles 162 secured to the tops of the doors. Figure 5 shows the track 92 supported on the frame of the furnace which extends across the top of the upper flange 13.  

Figure 5 also shows a detail of the thrust bearing 130. There is a semi-circular support 165 located in the top of each of the cover doors 102. When these cover doors 102 are brought together to close the top of the furnace, the semi-circular supports 165 form an annular seat on which a ball bearing thrust bearing 167 can rest. This thrust bearing 167 is carried by the hub of the bevel gear 120. When the support 111, and its connected bevel gear 120, are lowered, they come to rest with the thrust bearing 167 on the supports 165.

Figure 6 is a fragmentary detailed view of one of the bottom doors 89. These doors have a fire brick covering 170. The sides 172 of each door extend upward above the fire brick lining 170 around three sides of the door, that is, around all of the sides except the side that confronts the other door 89.

The track 92, on which the door 89 runs, is at such a level that the top surface of the fire brick 170 is just below the lower face of the bottom flange 15 of the furnace shell 12. In order to more adequately seal the bottom of the furnace, there are sheets of asbestos paper 176 held within the sides 172 in position to contact with the flange 15 and at least partially overlie the circumference of the flange so as to seal the clearance between the flange 15 and the fire brick lining 170 when the doors 89 are moved inward to their ultimate limits under the furnace 10.

Figures 7-9 show the construction of the support 111 with its flanges for holding and centering the workpiece 108. The construction includes two features which are of particular importance in connection with the heating furnace located directly over the quenching pit. One of these features relates to the quenching of the inside surface of the workpiece and the same time preventing a surge of quenching fluid upward through the workpiece, and out through the top of the workpiece with a resulting splash into the heating chamber of the furnace. The other feature relates to the quick attachment and detachment of the workpiece and the support.

The support 111 has its center stem 119 extend downwardly through a sleeve 180 to which the flanges 110 and 112 are directly connected by welding, or in any other suitable way. Gusset plates 182 brace the flanges 110 and 112 to keep them substantially normal to the axis of the sleeve 180. There are collars 184 pinned to the stem of the support 111 for holding the stem and sleeve in substantially coaxial relationship.

The lower end of the stem of the support 111 has threads 186 extending for a substantial distance upward from the lower end of the stem and there is a nut 187 which screws on the threads 186. In the preferred construction a washer overlies the nut 187.

The nut 187 and washer 188 are small enough to pass through the sleeve 180 easily. After they are in a position some distance below the lower flange 112, a bracket 190 is swung into position to partially close the opening at the bottom of the sleeve 180.

This bracket 190 swings about a pivot screw 192 which is carried by the flange 112. The bracket 190 has a slot located in position to straddle the lower end of the stem above the nut 187 and washer 188. This slot in the bracket 190 is smaller than the nut and washer so that the sleeve 180, with its flanges 110 and 112, cannot move downwardly on the stem of the support 111 as long as the bracket 190 is in a position straddling the lower end of the stem.

The nut 187 is screwed up or down along threads 186 to adjust the level of the workpiece along the support 111, and to obtain a resulting adjustment of the workpiece with respect to the different levels of burners in the heating chamber of the furnace. When the workpiece is to be removed from the support 111, the bracket 190 is swung into the dotted line position shown in Fig. 9. This leaves the lower end of the sleeve 180 open so that the stem of the support 111 can be pulled out of the furnace.
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5. The heat-treating apparatus comprised of a furnace located directly over a quenching pit, the furnace enclosing a heating chamber above the quenching pit, a work support for lowering a workpiece into the furnace and into the quenching pit, and for removing a workpiece from the quenching pit and from the furnace, said support including a holder for the workpiece and which holder extends through the top of the furnace when the workpiece is in position to be heated, a flexible element connected with the upper end of the holder and extending vertically upward from the holder and the furnace, a first guide located directly above the furnace and around which the flexible element passes, a second guide horizontally spaced from the first guide and around which the flexible element passes beyond the first guide and from which the flexible element extends to hoisting and lowering mechanism, a carriage by which the first guide is supported, and an arcuate track extending along a course which passes directly over the furnace and on which the carriage rides, the axis of curvature of said track passing substantially through a portion of the flexible element which extends from a second guide to the hoisting and lowering mechanism, the second guide being a wheel supported by a pivot having a substantially vertical axis of rotation substantially on said axis of curvature of the track.

6. In heat-treating apparatus adapted to be used with a furnace located directly over a quenching pit and a heating chamber of the furnace in direct communication with the quenching pit, and a partition movable into and out of position to separate the heating chamber from the quenching pit, said apparatus further adapted to hold a workpiece at a predetermined level in the heating chamber, mechanism for moving the support to raise and lower the workpiece with respect to the quenching pit and the heating chamber, said support including a vertically extending member adapted to pass downwardly into the interior of a hollow workpiece which is open at its upper and lower ends, the support including baffles adapted to fit within the workpiece and to extend across substantially the entire open interior of the workpiece for preventing an upward surge and splashing of quenching fluid through the top of the workpiece when the workpiece is lowered into the furnace, said baffles having clearance openings through which separated streams of quenching fluid move upward into the workpiece to quench its interior surface as the workpiece is lowered into the pit.

7. In heat-treating apparatus, a support for holding, at a predetermined level in a furnace, a hollow workpiece which is open at its upper and lower ends, and for raising and lowering the workpiece with respect to the furnace and a quenching pit immediately below the furnace, said support comprising a sleeve having a plurality of flanges extending therefrom, the flanges being of a size to extend substantially entirely across the cross section of the open interior of the workpiece to serve as baffles for preventing excessive surging of the quenching fluid up through the workpiece with resulting splashing from the top opening of the workpiece, said flanges having openings through which streams of quenching fluid travel upwardly to fill the workpiece above the flanges extending therefrom, the support including also a rod which passes downwardly through the sleeve and beyond the lower end of the sleeve, and releasable means attaching the sleeve to the rod.

8. A heat-treating furnace including an inside wall and heaters located on the inside wall, a furnace top comprising reciprocating doors that come together to close the upper end of the furnace and that move apart to open the furnace at its upper end, a workpiece support

2. The heat-treating apparatus described in claim 1, with another bevel gear supported by a power driven shaft extending transversely of the rod and located in position to mesh with the gear on the rod when that gear is supported by the thrust bearing on top of the doors.

4. Heat-treating apparatus comprising a furnace located directly over a quenching pit, the furnace enclosing a heating chamber above the quenching pit, a work support for lowering a workpiece into the furnace and into the quenching pit, and for removing a workpiece from the quenching pit and from the furnace, said support including a holder for the workpiece and which holder extends through the top of the furnace when the workpiece is in position to be heated, a flexible element connected with the upper end of the holder and extending vertically upward from the holder and the furnace, a first guide located directly above the furnace and around which the flexible element passes, a second guide horizontally spaced from the first guide and around which the flexible element passes beyond the first guide and from which the flexible element extends to hoisting and lowering mechanism, a carriage by which the first guide is supported, and an arcuate track extending along a course which passes directly over the furnace and on which the carriage rides, the axis of curvature of said track passing substantially through a portion of the flexible element which extends from a second guide to the hoisting and lowering mechanism, the second guide being a wheel supported by a pivot having a substantially vertical axis of rotation substantially on said axis of curvature of the track.
including a shaft extending downwardly through an opening in the top doors where they come together and through the upper end of the furnace and vertically movable with respect to the furnace, mechanism that rotates the shaft to turn the workpiece with respect to the heaters in the furnace, said mechanism including a gear secured to the shaft and movable as a unit with the shaft and located at a predetermined level above the top of the furnace when the support is in position to hold the workpiece in its intended heating position in the furnace, a driving gear that meshes with the gear on the support when the latter is in heating position, power driving mechanism for said second gear, a thrust bearing surrounding said opening in the top door and on which the gear of the shaft is carried while the support is being rotated during a heating operation.

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