Aug. 25, 1942. J. J. CROWE **2,294,161**

FLAME HARDENING

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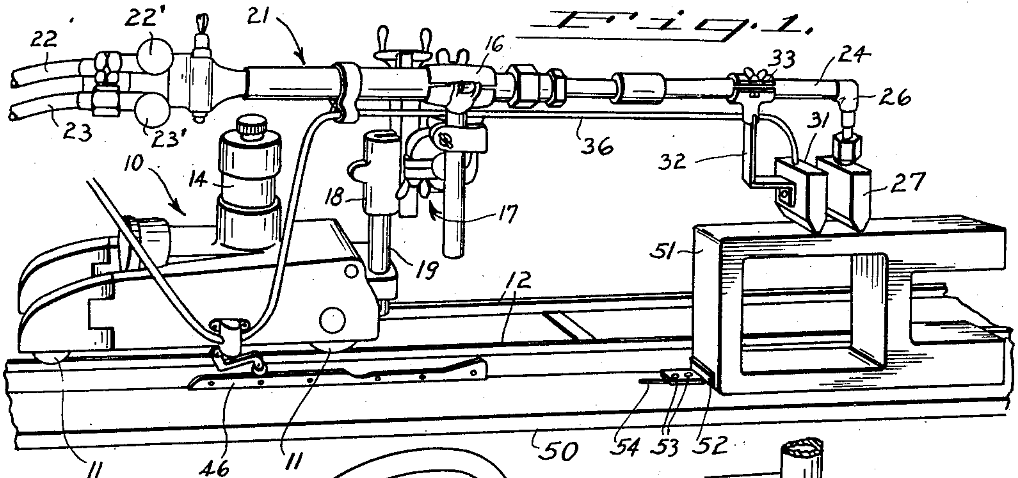


Fig. 1.

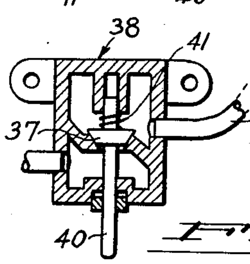
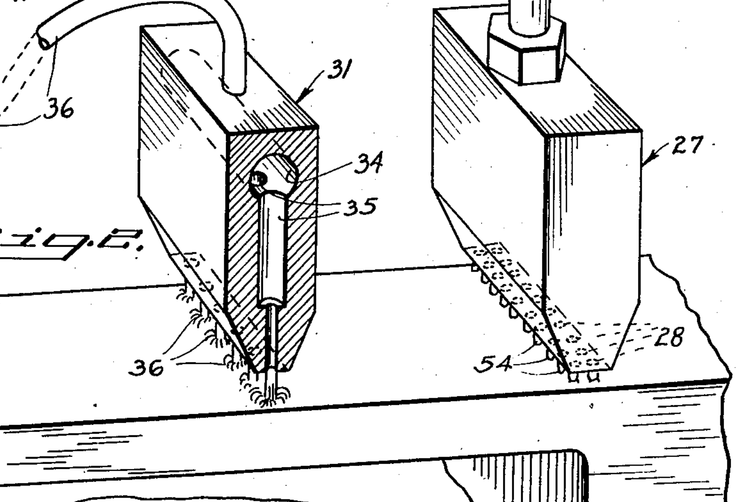


Fig. 2.



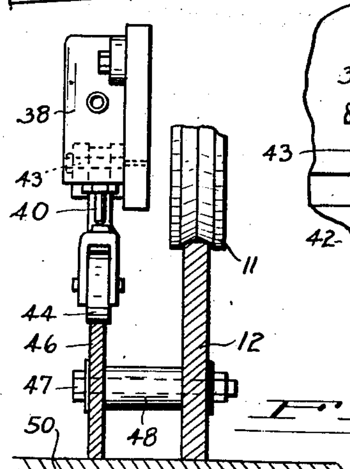


Fig. 4.

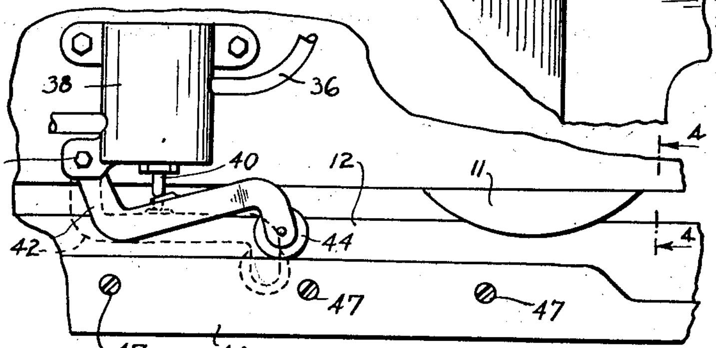


Fig. 3.

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FLAME HARDENING

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7 Claims. (Cl. 148—19.9)

This invention relates to flame hardening, and more particularly to the control of the depth of the hardening, especially with work-pieces of variable section.

Since the surface metal is heated quickly and steep temperature gradients are produced in the metal of the work-piece during flame hardening operations, the mass of metal to which heat is lost by conduction seriously influences the results obtained. The interior metal in a heavy section may withdraw heat from the surface and the metal just below the surface so rapidly that the temperature will be too low to obtain the desired hardening when the quenching water is applied.

On another region of the same work-piece, where the section of metal is thinner and less heat is lost by conduction, the quench will be more severe because of the higher temperature of the metal and the hardening operation therefore more effective. In order to prevent such variations in hardness and depth of hardness, it has been proposed to change the amount of heat put into the metal in such a way as to compensate for the variation in conduction losses.

It is an object of this invention to provide a simplified method and apparatus for controlling flame hardening results on work-pieces of varying section, and more especially for obtaining uniform hardening of such work-pieces. With this invention the hardening operation is controlled by regulation of the quenching jets, preferably by changing the velocity and volume of quenching fluid in accordance with changes in heat losses to the underlying metal. The amount of heat supplied is sufficient to heat the metal at the regions of greatest thickness and the supply of quenching fluid is made to vary inversely with the conduction losses from the surface metal to the metal below the surface.

There is rapid and substantial transfer of heat through the metal from the region under the flames to the region cooled by the quenching jets. An increase in the supply and velocity of quenching fluid causes an increase in the heat flow from the region of the flames. A decrease in the quenching fluid makes the temperature gradient between the heating and quenching regions less steep and causes a reduced heat flow.

With this invention the supply of quenching fluid is increased when the torch operates on thinner sections to counteract the reduced conduction losses to underlying metal. When the section under the torch is thicker, the volume and velocity of the quenching fluid is reduced to compensate for the larger conduction losses to the increased mass of metal under the heating torch.

Although this invention can be used in combination with other expedients for obtaining uniform or controlled hardening at different regions of a work-piece, it is not ordinarily necessary to use any variation in heat or other expedient with the variable quench of this invention. It is a feature of the invention that a uniform supply of heat can be maintained as the hardening operation progresses along the work-piece, and the variations in conduction losses are compensated for by variations in the quenching fluid supply.

Such a control of the hardening by regulating the quenching fluid is simple and has certain advantages over heat variation in that there is only one quenching fluid supply line whereas there are two gases, and quenching fluid can be discharged at any desired velocity whereas most heating torches operate best at only one gas pressure, and if the velocity of gas discharge is much reduced the torch will flash back.

The invention will be described as applied to the hardening of one face of a work-piece. In speaking of hardening the face of the piece it should be understood, however, that the term "face" is used to denote not only the actual surface metal but also the layer of metal immediately below the surface.

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

In the accompanying drawing, forming a part hereof:

Fig. 1 is a perspective view showing apparatus for flame hardening a work-piece in accordance with this invention.

Fig. 2 is an enlarged view, partly in section, showing the heating torch, quenching head, and control valve of Fig. 1.

Fig. 3 is an enlarged detail view of the quenching fluid control valve and cam operating mechanism, shown in Fig. 1.

Fig. 4 is a sectional view, taken on the line 4—4 of Fig. 3, but with the cam-follower on a low part of the cam.

A supporting means comprising a torch carriage 10 has four wheels 11 that run on a track 12. The carriage is self-propelled, being driven by a governor-controlled motor 14 that is connected with the front wheels of the carriage by suitable reduction gearing, not shown, but well understood in the art.

A torch holder 16 is supported by a universally adjustable bracket 17 that has a clamp 18 securing it to a post 19 that extends upward from the front end of the carriage. A torch 21 in the torch holder 16 is supplied with oxygen and fuel gas, preferably acetylene, through separate hose 22 and 23, respectively. The supply of gas from these hose is controlled by valves 22' and 23' at the back end of the torch. In the illustrated apparatus, the torch 21 has an extension tube 24 with an elbow 26 at its forward end. A tip 27 is connected with the elbow and has a double row of orifices 28 (Fig. 2) in its bottom face to which gas is supplied from a common distributing chamber in the torch.

The clamp 18 can be turned on the post 19 so that the torch 21 extends at a slight transverse angle to the track 12, and the tip 27 can be adjusted with respect to the elbow 26 to bring the torch into position with the rows of orifices 28 in the tip face extending at right angles to the direction of movement of the tip as the carriage 10 travels along the track 12.

A quenching head 31 is positioned close behind the heating torch and supported by a bracket 32 which is ultimately supported from the carriage. In the illustrated apparatus, the bracket 32 is attached to the extension tube 24 of the torch by a clamp 33, and the bracket 32 is slightly offset so as to locate the quenching head 31 directly behind the heating torch 27. The clamp 33 can be shifted lengthwise along the extension tube 24 to change the spacing of the quenching head 31 from the heating torch 27.

Fig. 2 shows the quenching head 31 in section. A common distributing chamber 34 supplies cooling fluid to a row of jet passages 35 that are of reduced diameter at their lower ends where they open through the bottom face of the quenching head. The cooling fluid, which is preferably water, is supplied to the quenching head through a supply line comprising a tube or conduit 36 commanded by a valve 37 in a housing 38 attached to the side of the carriage 10. The water discharges from the quenching head 31 in quenching jets 39.

A valve stem 40 extends through a stuffing-box in the bottom wall of the housing 38. The valve 37 is urged toward closed position by a spring 41, and is opened by a lever 42 which is cam-operated. One end of the lever 42 is connected by a pivot 43 to lugs on the valve housing 38. A cam-follower roller 44 at the other end of the lever 42 rolls on a cam 46 extending along the side of the track and preferably attached to the track by bolts 47, though spaced from the side of the track by spacers 48 (Fig. 4).

A work support or table 50 at one side of the track 12 supports a work-piece 51 in position to be hardened by the operation of the torch 27 and quenching head 31. In order to have the cam 46 change the extent of opening of the valve 37 at the same time that the quenching head 31 reaches a region where the thickness of the work-piece changes, it is necessary that the work-piece be accurately positioned with respect to the cam. A limit stop 52 connected with the work table 50 by bolts 53 serves to position the work-piece accurately with respect to the cam 46. The bolts 53 extend through a slot 54 in the work table so that the position of the stop 52 can be adjusted for any changes in the spacing of the quenching head 31 from the carriage 10 when the clamp 33 is moved lengthwise along the extension tube 24.

There is a different cam 46 for every different shape of work-piece that the apparatus is called upon to harden. The contour of the cam 46 shown in Fig. 1 is designed for the work-piece 51.

The hardening operation is started by bringing the carriage 10 into position to locate the tip 27 over the left end of the work-piece 51 with flames 54 burning. The carriage is held stationary or moved very slowly at first when initially heating a cold work-piece. The roller 44 is beyond the left end of the cam 46 when the operation begins, and the roller 44 is in its lowest position with the cooling fluid control valve 37 closed.

The carriage 10 is then started under its own power and it moves along the track 12 at a speed which is determined by the governor of the motor 14, the speed being sufficiently slow to enable the heating flames to raise the metal over which they pass to a temperature well above the critical temperature of the metal. By the time the quenching head 31 reaches the work-piece 51 the roller 44 has reached the cam 46 and been displaced by the steep rise at the left end of the cam. This movement of the cam-follower opens the valve 37 and supplies cooling fluid at high velocity and in ample volume to not only quench the work-piece, but to withdraw considerable heat from the region under the torch where the section is relatively thin and conduction losses limited accordingly.

When the torch 27 reaches the web just beyond the center of the work-piece 51, the supply of quenching fluid is reduced by a drop in the cam 46. The reduced cooling by the quenching jets offsets the increased cooling by the additional conduction losses into underlying metal at the region over the web.

As the torch 27 passes beyond the web, the quenching fluid supply is increased by a slight rise in the cam 46, but since the section is considerably thicker than that ahead of the web, the quenching fluid supply is less than that used before the torch 27 reached the web.

Near the end of the work-piece where there is little metal ahead of the torch into which heat can flow, the supply of quenching fluid is increased to a maximum in order to compensate for reduced heat flow into metal ahead of the torch by increasing the heat flow toward the region of quenching.

Thus the displacement contour of the cam 46 is so related to the variations in the thickness of the metal under the top surface of the work-piece 51 that the supply of quenching fluid (and consequent velocity or strength of the quenching jets 36) varies in accordance with changes in the thickness of the work-piece. Since conduction losses from the face that is heated are greater in proportion to the mass of metal below the surface, the cam operation described changes the supply of quenching fluid inversely with changes in the thickness of the work-piece. Any change in the right direction is beneficial in that it makes the hardening results more uniform, but as in the case of all flame hardening operations, the actual numerical values for gas pressure, carriage speed, and water pressure for best results depend upon so many interrelated variables that their determination must be largely empirical in accordance with practices well known in the art.

The envelope gases from the heating flames flow over the work-piece and blanket the surface between the heating flames and quenching jets so that the hot metal is protected from the atmosphere.

The invention is not limited to the embodiment described, various changes and modifications can be made, and some features of the invention can be used without others.

I claim:

1. The method of producing a more uniformly hardened face on a work-piece that is of variable thickness below said face and of material that can be hardened by cooling quickly from above a critical temperature, which method comprises heating the face to be hardened by means of heating flames applied progressively to the face in a manner that supplies substantially equal heat input to the regions of different thickness, directing jets of quenching fluid against the heated face close behind the progressively-applied heating flames, and reducing the quench at regions where greater thickness of the metal causes larger heat loss by conduction.

2. The method of flame hardening a work-piece that is made of material that can be hardened by cooling quickly from above a critical temperature, which method comprises moving a system of heating flames progressively across the part to be hardened followed by a system of quenching jets, and compensating for variations in the heat loss by conduction at sections of different thickness by changing the velocity of the quenching jets inversely with changes in the conduction losses to the metal adjacent the heating flame.

3. In the flame hardening of a work-piece made of metal that can be hardened by moving heating flames progressively across the face to be hardened to raise the metal above a critical temperature, followed by quenching jets close behind the heating jets, the improvement which comprises controlling the hardening by varying the supply of quenching fluid to said jets inversely with the variations in the conduction losses from the surface metal against which the heating flames are directed.

4. The method of flame hardening a work-piece that is of different thickness at different regions lengthwise of the surface to which heating flames and quenching jets are applied and of material that can be hardened by cooling quickly from above a critical temperature, which method comprises heating the work-piece progressively along the length of said surface by moving a constant number of uniform heating flames at substantially uniform speed, following said heating flames with quenching jets directed against the heated work-piece close behind the heating flames, and regulating the supply of quenching fluid to the jets, during the progression of the quenching jets, in accordance with changes in the thickness of the work-piece.

5. In the flame hardening of a metal work-piece that is heated above a critical temperature by flame jets which are moved progressively across the surface of the work-piece but which leave the metal a short distance behind them at various temperatures at different regions across the work-piece because of variations in conduction losses resulting from differences in the mass of metal below the heated surface, the improvement which comprises cooling the metal quickly from above its critical temperature by progressively applying quenching jets to the work-piece close behind the heating flame jets and controlling the quenching jets to cool the metal more at the regions where the conduction losses to the underlying metal of the work-piece are the least.

6. Flame hardening apparatus including in combination a carriage movable along a support, means for supporting a work-piece in a fixed position with respect to the carriage support, a heating torch and a quenching header supported by the carriage, a conduit through which quenching fluid is supplied to the header, a valve on the carriage commanding the conduit, a cam-follower on the carriage for operating the valve, a cam extending for considerable distance along the course of movement of the carriage in position to operate the cam-follower and valve to adjust the rate of flow of quenching fluid to the header, and means holding the cam in a fixed position with respect to the work-piece, said position being correlated with the distance of the cam-follower from the quenching header so that longitudinal displacement of the cam-follower along the cam corresponds to displacement of the header over a predetermined section of the work-piece.

7. Apparatus for flame hardening as described in claim 6 with adjustable means for determining the spacing of the quenching header from the heating torch.

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