Flame Hardening Apparatus

Albert L. Hartley and Adolph H. Davis, Cincinnati, Ohio, assignors to The R. K. LeBlond Machine Tool Co., Cincinnati, Ohio, a corporation of Delaware

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1 Claim. (Cl. 266—4)

This invention pertains to an improved apparatus for surface hardening metallic objects. More particularly, this invention pertains to a metallurgical apparatus for surface hardening gear teeth in which the flame is traversed longitudinally along the gear tooth. The flame hardened portion and the soft root and fillet portion be

tween the gear teeth when only its working faces are surface hardened.

It is therefore a object of this invention to provide apparatus to effect a flame hardening operation for gear teeth which is not confined to the working surfaces of the gear teeth but which also treats the fillets and root areas adjacent thereto in the same manner so as to provide a uniform, uninterrupted flame hardened surface for the intertooth space. In this way there will be no points of stress or possible fatigue failure adjacent the base of the teeth as in former practices.

Still another object of this invention is to provide an improved apparatus for surface hardening gear teeth which effects an uninterrupted flame hardened surface in the intertooth space or crotch between the teeth, including the working face, the fillets, and the root areas between the teeth.

Still another object of this invention is to provide an improved means for applying the flames of a flame hardening apparatus to the teeth of a gear to be flame hardened so as to effect more efficient heat application to the gear teeth surfaces to be hardened with a minimum of thermal distortion and a greater degree of nicety of control of the flame hardening process.

Another object is to provide apparatus for flame hardening gear teeth by the application of surface heat treatment to adjacent working faces of the intertooth space between a pair of gear teeth and the root area therebetween in a simultaneous progressive manner.

And it is still another object to provide a method of flame hardening gear teeth by which a greater degree of quenching and heat control for portions previously flame hardened may be had.

Still another object is to provide apparatus for surface hardening gear teeth, utilizing the gas blow pipe form of heating device in which the entire intertooth space, including the root and fillets, is subjected to the same surface hardening temperatures as the working surfaces of the gear teeth so as to reduce fatigue failure at the base of the teeth and to thereby increase the life and dependability of the gear.

Another object is to provide an improved method for surface hardening gears, particularly the portions which are subjected to the greatest amount of wear and stress during operation, and to perform these improved surface hardening effects in a simple and inexpensive manner.

A further object is to provide an improved
method for progressively simultaneously flame hardening adjacent facing working surfaces of a pair of teeth, together with their associated fillets and root area, to a uniform depth of heat treatment to thus cause the physical properties of the material along this entire surface to be such as to provide an uninterrupted strengthened surface for the gear structure.

The above objects are attained in brief by providing an improved burner and also an improved method of operating the burner. The burner is so designed as to conform to the contour of the space between the teeth of the gear, rack, or any similar work configuration. This burner is provided with means for separating the flame area from the quenching area and also contains additional rows of coolant holes for protecting the outer contours of the teeth from becoming drawn or softened while the inner surfaces are being subjected to temperatures above the upper critical point for the material being treated.

The invention will be better understood when reference is made to the following description and the accompanying drawings, in which:

Figure I is a front elevation view showing the burner being applied to the teeth of a gear.

Figure II is a side view showing the improved surface hardening method being applied to a number of gears for simultaneous treatment.

Figure III is an enlarged view of one of the gears shown in Figures I and II, and indicating the optimum distribution of hardness penetration obtainable by this improved method and apparatus.

Figure IIIa is an enlarged fragmentary view of a gear showing the former method of flame hardening confined to the working faces of a gear tooth.

Figure IIIb is an enlarged fragmentary view of a gear showing the present method of flame hardening the entire intertooth space between a pair of gear teeth.

Figure IV is a view looking from the right of the flame hardening burner.

Figure V is a plan view of the burner shown in Figure IV.

Figure VI is a view of the bottom of the burner shown in Figure IV, illustrating particularly the arrangement of the flame and quenching holes.

Figure VII is a vertical transverse section taken along line VII-VII of Figures IV and V to illustrate particularly the coolant chamber incorporated in the front portion of the burner.

Figure VIII is a vertical transverse section taken along line VIII-VIII of Figure IV to show, in particular, the gas chamber and its associated openings.

Figure IX is a transverse sectional view taken along line IX-IX in Figures IV and V showing particularly the coolant chamber with its associated openings as incorporated in the rear portion of the burner.

Figure X is a vertical section taken along line X-X in Figures VII, VIII, IX, illustrating the position of the openings for supplying coolant to the outer surfaces of the teeth.

In carrying out our method of flame hardening, the gear or gears I are mounted on a suitable mandrel 2 which in turn is supported on centers (not shown) with associated well-known apparatus for effecting relative traversing of the gear or gears past the burner and cooling head in order to surface harden the desired portions of the gears. Preferably a machine such as disclosed in the Groene Patent No. 2,264,752, granted December 2, 1941, and assigned to the same assignee as the present application may be utilized.

It was the former practice in surface hardening of gear teeth to confine the hardened portion to the working face of each tooth. This was considered sufficient as it was primarily the object in former practice to merely increase the wear resistance of the gear and not the resistance of the gear teeth to fatigue. The former practice is shown in Figure IIIa in which the flames F from the burner B were caused to impinge only on the working faces of gear tooth contact G of the gear so as to provide flame hardened portions C along these faces. Furthermore, this practice was followed because of the difficulty of disposing of the burned gases which could best be done, it was thought, by this arrangement wherein the burned gases might readily escape through the spaces S between the sides of the burner B and adjacent gear teeth.

While this method thus provides some measure of improvement in the wear characteristics of the working face of the gear tooth, an inherent weakness is developed in the gear tooth structure at the point P which is the line of demarcation between flame hardened material C and the untreated core or gear body merges with the tooth surface near its base and juncture with the root area between the gear teeth. This is caused by the fact that the flame hardened material C tends to expand relative to the untreated core material in the gear so that the mass of core material holds the material C under compression after the completion of the flame hardening process. Thus there is a tendency for fracture and cleavage to develop at the points P which is particularly aggravated by an application of load to the working faces of the gear teeth when in operation. Thus, in time, a fracture may develop at the point P and travel through the gear tooth base along the line D which ultimately results in the fracture of the gear tooth.

In this new method a flame hardening burner 3 is mounted by the usual connecting conduit 4 to the mixing chamber of a flame hardening torch (not shown), using in this case mixed acetylene and oxygen as its heating medium. The burner is adjusted to fit in the interspace or slot formed by two adjacent teeth 71 and 72, Figure IIIb, of the gear I. The burner is progressively traversed longitudinally along the gear teeth in the direction of travel shown in Figure II. When the burner 3 has finished its traverse across the gear teeth, the flame is then extinguished and the burner 3 is returned to its initial starting position, at which time the gears are indexed in any suitable manner to the next space and the procedure again repeated.

In Figures III and IIIb, the shaded areas H indicate the ideal or optimum distribution of hardness to be provided on the working faces 5 and in the fillet and root areas 6 between a pair of gear teeth. This flame hardened portion H, it will be noted, comprises an uninterrupted hardened surface extending from the tip of one gear tooth down through its working face, through the fillets and root portions between it and the next adjacent tooth, and up through the working face of said adjacent tooth to its tip. There is thus provided a homogeneous continuous flame hardened portion H. This portion is maintained under compression due to the rigid unaltered core material and has no break or interruption in structure such as the points P. Figure IIIa, as occurs in former practice. Since fatigue failures result
only from tension stresses, maintenance of the area H in uninterrupted compression results in a gear structure highly resistant to fatigue.

The outer surface H is flame hardened simultaneously by a newarrangement of the burner which is applied in the intertooth space or crotch formed between the gear teeth T1 and T2, Figure IIIb. The burner is so arranged as to efficiently and accurately develop the flame hardened surface area H by providing alternating headers and an arrangement of flame jets and coolant jets so as to effect this result. Furthermore, an additional cooling arrangement is provided for the outer face T3 opposite the faces being hardened, the coolant being distributed over a wide area extending longitudinally of these faces T3 so as to maintain the interior structure of the gear teeth unaltered during the flame hardening process.

In Figures IV, V, VI, VII, VIII, IX, and X, elevational and sectional views of the improved burner is shown, this burner having a unique construction in which the threaded portion 11 is provided for coupling with a standard flame hardening torch 4. In general, the surface hardening unit is formed of three integral sections, all contained within a single casting or metal forming and having a guide plate in the unit, and are provided by some of the sections in order to effect the best results. The first section of the unit, as illustrated in Figure VII, comprises a series of cylindrical compartments 8, 9, 10, and 11, of which compartment 8 extends vertically, compartment 9 extends horizontally, and compartments 10 and 11 extend diagonally. These compartments merge together at the lower end of the section to form in effect a reservoir for a coolant as will be explained hereinafter. The compartments are formed in the easiest manner by boring or drilling large holes at the proper positions and then plugging up the outer ends of the holes by pipe plugs. The combined chamber or reservoir formed by the various compartments is in communication through a pair of oppositely disposed longitudinal extending openings 12 with another chamber formed by the holes or compartments 13, 14, and 15 located in the rear portion of the unit 3, as shown in Figure IX. These holes 13, 14, and 15 are also appropriately plugged and two of them extend diagonally through the unit while the compartment or opening extends horizontally. It will be noted that the opening 12 which passes into the front portion of the unit 3 has an ingress at the compartment 15. As in the case of the front section, the small compartments 13, 14, and 15 all merge together to form a reservoir and vertical openings 16 extend upwardly from this reservoir to terminate in a circular chamber 17 formed in the stem of the unit. The chambers in the front and rear sections of the unit provide ideal cooling conditions for the middle or burner section, as shown in Figure VIII, which being operated is under the influence of very high temperatures.

The lower surface of the front section of the unit 3, as shown in Figure VII, is provided with projections 25 of a substantially V-shape with a lowermost or flat surface of the projection 25 does not extend as far down as the depth of a tooth but instead there is an appreciable space left between the working surfaces including the root of the teeth and all of the face portion so as to effect this result. Furthermore, a downwardly depending pro-
trally positioned opening 23 extending from the upper surface of the screw plug 7 in a direction slightly diagonal, as indicated in Figure V, to communicate with the chambers 21, 22. A mixture of acetylene and oxygen is applied to the opening 23 through the blowpipe so that the chambers 21, 22 constitute a reservoir filled with this mixture. For emitting a pattern of flames to the surfaces being flame hardened, a series of openings 24 which form the flame jets are provided, these openings extending from the V-shaped opening 23 to the gas chamber. It will be noted that there are a large number of these openings and they extend uniformly over the entire curved surfaces of the V-shaped projection and also along the lowermost flat horizontal surface of the projection. This is important because it permits the jet flames to not only strike against the curved wearing surfaces of the teeth but also the fillets and the root areas. As shown in Figure VI, there are preferably two rows of jet openings 24, these rows being spaced apart a distance depending on the width of the tooth in order to uniformly heat all of the surfaces of the teeth including the root areas but excluding the tips.

The V-shaped projection 19 of the coolant section, Figure IX, extends for a greater depth than the corresponding projections of the heater section, which communicate with the chambers 13, 14, and 15 are considerably removed from the openings 24 in the burner section since the openings 18 are positioned in a single row and emerge at a tapered surface, indicated at 27, formed at the coolant section end of the burner on the opposite side of the shoulder point 26 from burner openings 24. Thus, there can be little or no interference between the two sets of openings 24 and 18, and each set will perform its individual function of first heating the wearing surfaces of the teeth (except the tips), also the fillets and root areas, and then suddenly quenching the heated areas to obtain a surface hardening effect without permitting the cooling fluid from substantially detracting from the heating effects offered by the jets 24.

The coolant discharge outlets 20 are so positioned relative to the flame jets 24 that the gear teeth being operated upon serve to shield the coolant from interference with the flames by confining the coolant to the outside working surfaces 23 of the pair of teeth being hardened, as best seen in Figure III.

It has been found that when a head or burner unit 3 having the three sections described above is caused to move longitudinally of the inter-space between a pair of gear teeth, as shown in Figures II and IID, the adjacent wearing surfaces of the teeth together with the fillets and root area will be first heated above the critical temperature and then immediately thereafter will be quickly cooled to obtain a hardened surface which is overstressed by the unaltered core of the entire surface including the root areas for providing added strength and resistance to fatigue failure of the gear. The original material at these heated surfaces is changed from a pearlitic or sorbitic structure to a hardened martensitic structure of expanded volume and the entire surface including the root areas are thus placed under compression due to this change which takes place in the internal structure of the material.

Thus, with this improved technique in which the fillets and root areas as well as the working surfaces of the gear teeth are flame hardened, gears or racks treated in this manner have been found capable of sustaining unusually heavy loads and of operating without fatigue failure or appreciable wear over long periods of time.

While the apparatus herein disclosed and described constitutes a preferred form of the invention, it is to be understood that the apparatus is capable of mechanical alteration without departing from the spirit of the invention and that such mechanical arrangements and commercial adaptations as fall within the scope of the appended claims are intended to be included herein.

Having thus fully set forth and described this invention, what is claimed as new and desirable to be secured by United States Letters Patent is:

In a flame hardening burner, for progressively flame hardening the gear tooth surfaces of the intertooth space between a pair of teeth of a gear, a burner body having a portion conforming to the shape of said intertooth space of the gear to be hardened, and heating, quenching, and cooling means in said portion including a series of flame jet openings in said portion, a series of quenching jet openings in said portion, a battie formed integral with said portion at an interspaced position between said flame and quenching jets, a series of tooth cooling jets located in the body portion of said burner in rows parallel to the direction of progressive movement of gear tooth and burner including jet openings for projecting coolant normal to said direction of progressive movement so as to direct a cooling liquid to the outside faces of the pair of gear teeth being hardened at a point opposite point of engagement of the flames on the faces of the teeth in the intertooth space, passageways in said body for conducting a source of fuel to said flame jets, and further passageways for conducting a source of quenching and cooling liquid to said quenching and cooling jet openings.

ALBERT L. HARTLEY.
ADOLPH H. DAVIS.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,711,839</td>
<td>Davis</td>
<td>May 7, 1929</td>
</tr>
<tr>
<td>2,188,637</td>
<td>Walker</td>
<td>Jan. 30, 1940</td>
</tr>
<tr>
<td>2,230,002</td>
<td>Rollman et al.</td>
<td>Oct. 29, 1940</td>
</tr>
<tr>
<td>2,254,308</td>
<td>Mott et al.</td>
<td>Sept. 2, 1941</td>
</tr>
<tr>
<td>2,273,809</td>
<td>Kinzel</td>
<td>Feb. 17, 1942</td>
</tr>
<tr>
<td>2,274,661</td>
<td>Gridley</td>
<td>Mar. 3, 1942</td>
</tr>
<tr>
<td>2,294,187</td>
<td>Kullman et al.</td>
<td>Aug. 25, 1942</td>
</tr>
<tr>
<td>2,312,839</td>
<td>Kullman</td>
<td>Mar. 2, 1943</td>
</tr>
<tr>
<td>2,433,055</td>
<td>Linden et al.</td>
<td>Dec. 23, 1947</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>225,333</td>
<td>Great Britain</td>
<td>Dec. 4, 1924</td>
</tr>
<tr>
<td>294,709</td>
<td>Great Britain</td>
<td>Aug. 2, 1928</td>
</tr>
<tr>
<td>484,365</td>
<td>Germany</td>
<td>Dec. 14, 1929</td>
</tr>
</tbody>
</table>