HEAT TREATMENT OF GEAR TEETH

Fig. 1

Fig. 2

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The present application as a continuation in part of our co-pending application, Serial No. 174,610, filed November 15, 1937, is directed to apparatus and method for the heat treatment of projections on the surfaces of articles, particularly projections such as gear teeth on metallic articles.

The invention herein disclosed is particularly well adapted to the heat treatment of projections which extend for some distances along the surface of the tooth such as the teeth of gears having wide faces. With our apparatus and method it is possible to provide the article with a preliminary heat treatment to produce a core having the desired physical properties as to strength and ductility and then to provide a surface zone of such depth and of such hardness and localized in such parts as will provide high resistance to wear and abrasion and simultaneously prevent warping or other distortions which would cause noisy operation or which would set up local strains of a harmful nature in parts of the article.

In general, the object of the invention has been to provide a method and apparatus for hardening internal or external projections on a member of the class mentioned above.

A further object of this invention has been to provide a gear or other article of the general character of a gear having hard surface zones to resist wear on contacting surfaces. Another object has been to provide a metal tooth or rib having a tough and ductile core and root section adapted to resist heavy bending or other stresses caused by shock or impact in the section in which such high stresses occur. An additional object has been to provide a tooth having a hard surface zone so bonded to the core or underlying metal as to resist cleavage of this hard zone. A still further object has been to provide a method of procedure in the formation of such hard surface zone on a tooth previously formed and heat treated for the desired core characteristics. A further object has been to provide apparatus adapted to be used in the practice of the process, which apparatus is easily constructed and which does not require a high degree of skill for its operation.

Numerous other objects will become apparent from the following description in which details of forms of apparatus with which to achieve the results of our invention will be pointed out and novel and advantageous steps in the procedure for obtaining the desired results will be described.

It is to be understood that while our description and drawings relate to gears we do not confine ourselves to hardening gears alone but apply the invention to the various objects heretofore outlined.

When it is necessary to harden large areas, frequently the power available is not sufficient to heat all the desired parts of that area simultaneously. Therefore this area must be heated in sections. Small parts may be hardened progressively by causing the inductor to pass over the area from one portion to the other and quenching back of the inductor as fast as the inductor advances past part of the area heated. Alternatively, teeth or other projections of small or intermediate size may be heated and quenched without relative movement of the inductor and the teeth or projections and surface zones of several such teeth or projections can readily be hardened simultaneously.

The manner in which we accomplish our invention is illustrated by the following description and the appended drawings. The novel features of the invention are summarized in the claims.

In said annexed drawings:

Fig. 1 illustrates the general arrangement and form of an inductor for heat treating surfaces of three projections simultaneously taken as indicated at 4—4 of Fig. 2.

Fig. 2 is a section substantially at 2—2 of Fig. 1.

Fig. 3 shows a modification of the apparatus of Fig. 1 taken substantially at 3—3 of Fig. 4 and which is adapted to heat treat the surfaces of four projections simultaneously.

Fig. 4 is a section substantially at 4—4 of Fig. 2.

In Figs. 1 and 2 the inductor comprises conductors 36 and 37 joined at their outer ends as at 38 to form a loop, the loop lying substantially tangentially to the pitch line of the teeth. Current of suitable frequency is supplied by the transformer 39. The conductors are inserted in tooth spaces of the gear 40. The tooth spaces are usually adjacent spaces as shown, but this arrangement is not necessary since two or more teeth may intervene between the two spaces occupied by the conductors.

The location of a conductor is determined to a large extent by the frequency employed and the number of tooth surfaces it is desired to harden at one time. When the inductor is arranged substantially as shown in Fig. 4 and current of moderate frequencies such as 1000 to 2000 cycles per sec. is employed the sides of tooth 41 are heated with a relatively small amount of heating in the sides of teeth 42 and 43, these being outside of the loop. The heating effect in the teeth is increased by reducing the spaces between the teeth and the inductor members 36 and 37. When the
frequency is materially increased, for instance to the order of 100,000 cycles, per sec., effective heating current will be generated in the adjacent surface zones of teeth 42 and 43 outside of the loop as well as in the surface zones of tooth 41 adjacent to the conductor members within the loop. To produce heating in the teeth, the spacing is changed to correspond with the frequency. As the frequencies become lower, the space between the tooth 41 within the loop, and the conductor, such as 37, becomes greater and the space between the tooth outside of the loop, such as 42, and the conductor 37 becomes less. As the extremely high frequencies the spaces are nearly equal with the conductors enlarged to lie close to the surfaces of both teeth. The face of the conductor adjacent to the tooth surface is frequently formed to vary in distance from this surface so as to control the distribution of the heating, the least distance usually being at the top of the tooth. The conductors are usually hollow to provide passages for cooling water. Quenching is accomplished by conduits such as 44 and 45 which usually lie parallel with the tops of the teeth and which have outlet passages such as 46 disposed to direct the quenching fluid into the spaces between the conductors and the faces of the teeth, the flow being under pressure and sweeping over the surfaces of the teeth vigorously enough to remove bubbles of steam or other vapor forming on these surfaces during quenching.

To prevent the inductor members 36 and 37 from interfering with a free flow of the quenching fluid it is often desirable to remove the inductor during quenching. To accomplish this, the inductor is hinged as at 47 which permits the loop to be swung out of the tooth spaces and then brought back accurately in place to temper the hardened teeth or to come into correct relation with other teeth after the gear has been indexed into a new position.

After hardening the faces of one tooth such as 41 or the four surfaces of teeth 41, 42 and 43 adjacent to the inductor members, the number of surfaces depending on the form of the inductor, their spacing and the frequency employed, the inductor is moved away from the gear far enough to permit rotating the gear on its axis. The gear is then rotated by a suitable mechanism and indexed to hold another unhardened tooth or group of teeth in heating position. The inductor members are then brought back into the spaces between the teeth of the unhardened group.

When a more rapid rate of hardening is desired and sufficient current of high frequency is available an inductor of the form shown in Figs. 3 and 4 is employed. This inductor is composed of a central conductor 50 and two lateral conductors 51 and 52, the latter usually being smaller than conductor 50. Conductor 50 passes between two teeth such as 53 and 54 and supplies current to the conductors 51 and 52 which together serve as a return circuit. These latter conductors are located in tooth spaces adjacent to teeth 53 and 54 on the sides of these teeth opposite to the space occupied by conductor 50 and are in heating relation with teeth 53 and 54. The conductors are usually hollow to provide passages for fluid ordinarily serving for both cooling the inductor and quenching the teeth. Other conduits for additional quenching fluid, such as 55, are frequently employed and have outlet passages 57 arranged to project this quenching fluid under pressure against and along the heated faces of the teeth, the fluid entering the spaces between the teeth and the conductors. As in Figs. 4 and 5, the spacing between the inductor members and the teeth within the loops is greater than the spacing between these inductor members and the teeth outside the loops when current of ordinary high frequency is employed. Thus, the spaces at 58 become smaller and spaces at 59 when such current is used. On the other hand, when high frequencies are used the spaces at 59 become relatively smaller and become substantially equal to the spaces at 58 when extremely high frequencies are employed which is required for substantially equal heating in all the tooth faces.

It will be understood that projections of various kinds besides gear teeth can be heat treated by our process such as splines, cutters, teeth, and grinding or crushing elements. These projections are considered as extending outwardly from a surface whose general contour is determined by the bottom surfaces of spaces between these projections, such as the root surface of gear teeth. To prevent, or to reduce to harmless proportions, the heating in the root portion or surface of the article from which the projections extend, these and the faces of the teeth are arranged at a substantial distance from this surface while heating the surface zones of the projections.

Other modes of applying the principle of our invention may be employed instead of the one explained, change being made as regards the structure herein disclosed, provided the means stated by any of the following claims or the equivalent of such stated means be employed.

We therefore particularly point out and distinctly claim as our invention:

1. In apparatus for hardening surface zones of projections on a metallic article, the projections being spaced along a base surface of the article and extending outwardly from said base surface, a U-shaped conductor having substantially parallel opposite sides, each of the sides having a face adapted to be brought into substantially parallel relation with a surface zone of a projection, means for supplying periodically varying current to the conductor to induce heating current in the said surface zones, means moveably supporting the conductor at an end of a side of the conductor, means for guiding the conductor into a preselected position relative to a projection of the article when the conductor is moved toward the base surface of the article to bring a face of the conductor into spaced relation with a surface zone of the projection, and means for delivering quenching fluid to the surface zones of the projections, the quenching means comprising a quenching member disposed to lie substantially opposite an outer end of the aforesaid projection, the said quenching member having discharge passages directed toward a space adapted to be occupied by the projection of the article, the quenching member being of less width than the space between the conductor members to pass between the said members when the conductor is moved on its support.

2. In apparatus for simultaneously hardening four surface zones of projections on a metallic article, the projections being spaced along a base surface of the article and extending outwardly from said base surface, a U-shaped conductor having substantially parallel opposite sides, each of the sides having opposite faces adapted to be brought into substantially parallel relation with surface zones of adjacent projections when the
side is inserted between the adjacent projections, means for supplying periodically varying current to the conductor to simultaneously induce heating current in the four surface zones lying adjacent to the sides of the conductor, means moveably supporting the conductor at an end of a side of the conductor, said supporting means comprising means for guiding the conductor into a preselected position relative to the projections of the article when the conductor is moved toward the base surface of the article to bring faces of the conductor into spaced relation with corresponding surface zones of the projections, and means for delivering quenching fluid to the surface zones of the projections, the quenching means comprising spaced quenching members disposed to lie substantially opposite outer ends of the aforesaid projections, the said quenching members having discharge passages directed toward spaces adapted to be occupied by the projections of the article, and the sides of the conductor being of less width than corresponding spaces between the quenching members to pass between the said quenching members when the conductor is moved on its support.

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