Jan. 11, 1944. F. S. DENNEEN ET AL 2,339,157

METHOD OF HARDENING CONTIGUOUS AREAS

Filed May 27, 1940

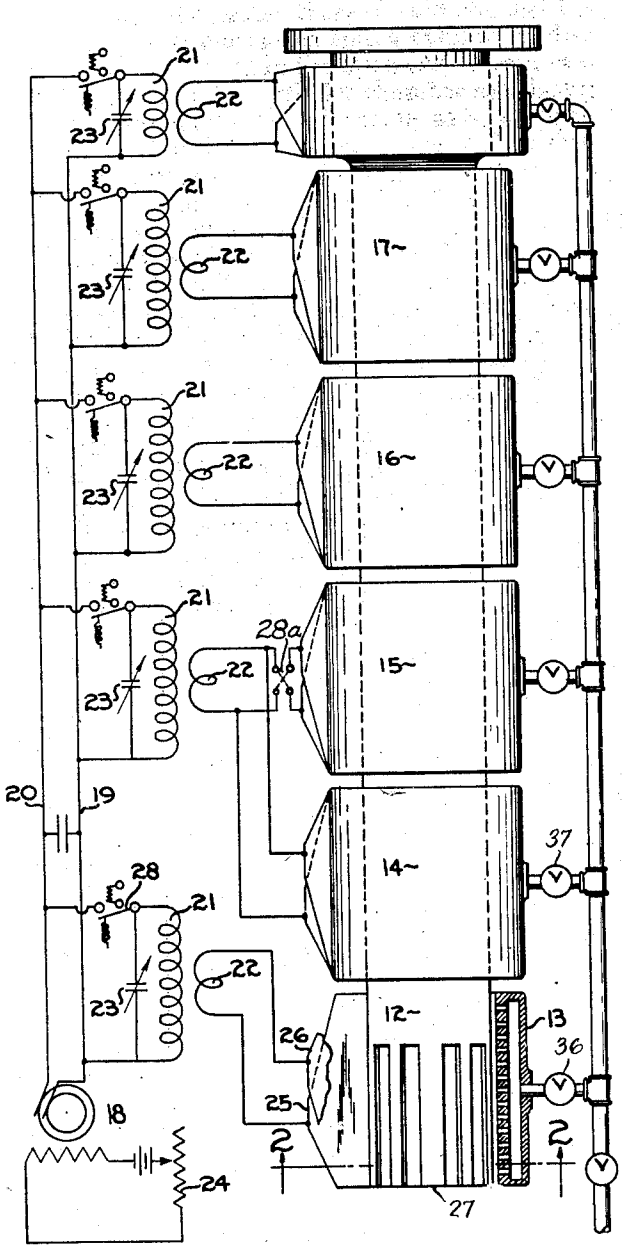



Fig. 1

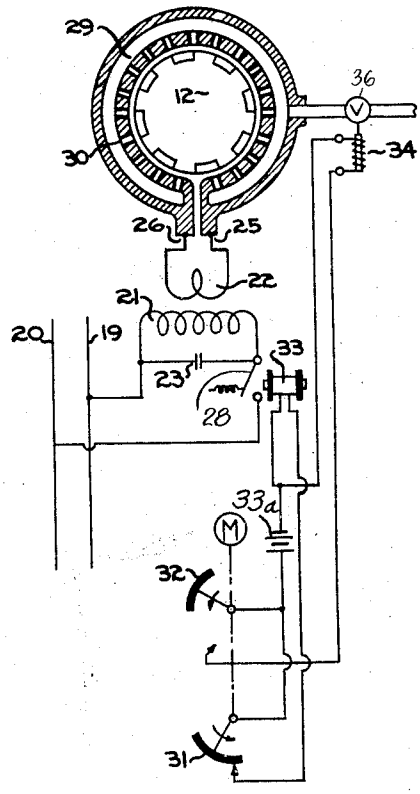



Fig. 2

INVENTORS

Francis S. Denneen

William C. Denneen

Patented Jan. 11, 1944 2,339,157

# UNITED STATES PATENT OFFICE

2,339,157

## METHOD OF HARDENING CONTIGUOUS AREAS

Francis S. Denneen, Cleveland, and William C. Dunn, Shaker Heights, Ohio, assignors to The Ohio Crankshaft Company, Cleveland, Ohio, a corporation of Ohio

Application May 27, 1940, Serial No. 337,428

4 Claims. (Cl. 219—13)

The present application is a continuation in part of our application Serial No. 54,388 filed Dec. 14, 1935, now Patent No. 2,202,759, issued May 28, 1940 and entitled "Heat treatment of shafts and the like" and is directed mainly to hardening substantially all of the axially extending surfaces of a shaft or similar article in such a way that adjacent areas are hardened to different degrees and/or different depths, the apparatus employed being adapted to harden all of the surfaces substantially simultaneously and in such manner that the hardened zones blend into each other without a distinctly marked line of change. However, the apparatus employed is capable of being so adjusted as to leave unhardened areas of any selected widths since intermediate unhardened areas are frequently required.

In view of the above conditions, the chief object of the present invention is to provide a method of hardening substantially simultaneously selected parts of a shaft or similar article, adjacent parts blending together but being of different characteristics. Another object is to provide a method of hardening several areas of a shaft selectively to the same or different degrees of hardness and leaving intervening areas substantially unhardened. A further object is to provide a method of controlling the rate and amount of quenching as well as the rate and amount of heating in such adjacent areas. An additional object is to provide a method which is sufficiently flexible to permit the use of equipment which is readily applicable to other shafts of approximately the same diameter but having variously arranged hardened zones.

With these and other objects in view, said invention then consists of the method hereinafter described. It will be understood that the following description is not intended to limit the scope of this invention and that the invention may appear in many embodiments differing in detail from this disclosure but within the scope of the appended claims.

The annexed drawing and following description set forth in detail certain mechanism embodying the invention, such described means, however, constituting but one of the various forms in which the principle of our invention may be used.

In said annexed drawing:

Fig. 1 illustrates the preferred form of our apparatus. Fig. 2 is a section on line 2—2 of Fig. 1 and diagrammatically includes means of control.

In the apparatus illustrated in the above figures, the shaft 12 is inserted in a series of parallel and relatively closely spaced inductors 13, 14, 15, 16 and 17, the surface of the shaft being spaced from the inner surfaces of the inductors. Heating current is supplied by the high frequency generator 18 which delivers this current thru the power lines 19 and 20. Suitable transformers having primaries 21 connected across these power lines and with secondaries 22 connected to the inductors serve as means for converting the relatively high voltage generator output into low voltage current of high density at the inductors. Condensers such as 23 are connected across the primaries so as to tune the circuits for the most suitable heating conditions. The generator output is controlled by the field resistance 24. The connections of the secondary coils to the inductors are made at points such as 25 and 26 which are substantially opposite for proper current distribution, the displaced positions indicated in Fig. 1 being for ease of illustration. It is customary to provide a transformer for each inductor. However, under some conditions, when the equalization or distribution of current to several inductors is not difficult, two or more inductors are connected to one secondary such as the connections illustrated for inductors 14 and 15.

As it is frequently required to regulate the heating and/or quenching to control the depth of the hardened zone or its degree of hardness at various parts of the shaft, means is provided to automatically take care of such conditions. For such parts as may require a deep hardened zone, as for instance the spline portion at 27, the heating is begun here somewhat in advance of heating at other parts. This is accomplished by closing switch 28 before closing other of the primary circuits and considerable heating is accomplished in advance after which the remaining circuits are closed.

The heating in various parts of shaft 12 is further controlled by changing the direction of current in one or more of the inductors relative to the direction of current in the other inductors. Thus if, for instance, the connections for the transformer supplying current to inductor 15 are reversed by means of switch 28*a*, the current in this inductor at any instant will be in a direction opposite to that which this current would have if the terminals had not been reversed, i. e., it will be 180° out of its original phase. The flux field produced by this inductor will then oppose that of inductors 14 and 16 of which the connec-

tions have not been changed and in which the current thus remains in its original phase relation. Since current in inductor 15 is thus in reversed or opposite phase relation to current in inductors 14 and 16, the flux threading thru inductor 15 will be of opposite phase to and will oppose and cancel a part of that threading through inductors 14 and 16, resulting in a greatly reduced heating effect, particularly in the regions of the shaft which are opposite the points where the inductors are adjacent to each other. Thus one or more regions of selected widths will be left unheated and unhardened, the locations and widths of which are determined by the relative positions of the two adjacent inductors.

A further control is readily accomplished by changing the power factor or phase relationship of the currents in two adjacent inductors with or without reversing the connections of one of them. Thus, if the condenser in the circuit supplying current to inductor 15 is variable and is adjusted to throw the current in this inductor materially out of phase relative to the current in inductor 16 a component of the current in inductor 15 will oppose the current in inductor 16 and the resulting flux field produced by both inductors will be changed, particularly that part lying in the region of the proximate sides of these inductors. This results in a convenient control of the heating in that part of the shaft affected by this part of the flux field. The heat treatment of various parts of the shaft is thus readily effected.

The automatic control of such heating and quenching is provided by rotating timer discs having contacts indicated at 31 and 32, the discs being driven by a synchronous motor M. These contacts close and open relay circuits at proper times to provide the heating and quenching desired. Contact 31 controls current supplied to relay 33 from source 33a for operating switch 28 in the circuit of transformer primary 21 to heat the article 12 for the required interval. Contact 32 controls current to relay 34 from the same source for operating valve 36 to apply quenching fluid during and at a prescribed interval of time after heating.

A further control of the intensity and distribution of heating is accomplished by reciprocating the shaft longitudinally relative to the inductors thru a distance predetermined by the spacing of the inductors and the heating intensity required the reciprocating being accomplished by imparting a reciprocating movement by any well known means to a member (not shown) which is used to support the shaft.

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

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

1. A method of surface hardening an article, the article being adapted to be hardened by heating and quenching comprising bringing said article into current inducing proximity with a series of inductors, the inductors being spaced along said article, providing a supply of periodically varying current for the inductors, the current in each inductor producing a flux field threading thru a part of said article to induce heating current in the article, the supply of current in one inductor being in timed relation to the current supply to an adjacent inductor to heat the part of the article in proximity with the one inductor for a greater interval of time than the part in proximity with an adjacent inductor, continuing to supply current to both of said inductors to heat both of said parts of the article simultaneously, selecting the phase of current in one inductor relative to the phase of current in the other inductor to prevent harmful heating in a part of the article between the inductors, and interrupting the supply of current to both of said inductors.

2. A method of surface hardening an article, the article being adapted to be hardened by heating and quenching, comprising bringing said article into current inducing relation with a series of inductors, the inductors being spaced along the article, providing a supply of periodically varying current for said inductors, the current in each inductor producing a flux field threading through a part of said article to induce heating current in the article, reversing the direction of current in one inductor relative to current in the other inductor to reverse the flux field produced by the one inductor, the flux field of one inductor substantially cancelling the flux field of the adjacent inductor at the region of adjacency of the inductors and then shifting the phase of current in the one inductor to reestablish a predetermined component of the cancelled flux field to provide a predetermined amount of heating in the article at the region of adjacency.

3. A method of inductively heating two closely spaced zones of an article comprising bringing the zones into current inducing proximity with separate inductors, the inductors being so closely spaced along the article that periodically varying current of substantially the same phase and frequency when supplied to said inductors simultaneously will heat said zones and will produce a flux field in the space between the inductors to heat an intermediate part of the article lying between said zones substantially as intensely as the zones are heated, connecting the inductors to separate circuits, the said circuits being adapted to supply inducing current of the same phase to both of the inductors, and changing capacity in said circuits to shift a flux field being produced by current in one inductor sufficiently out of phase relative to a flux field being produced by current in the other inductor to substantially cancel the flux field in the space between the inductors to substantially eliminate a generation of heating current in the aforesaid intermediate part of the article.

4. A method of inductively heating two closely spaced zones of an article comprising bringing the zones into current inducing proximity with separate inductors, the inductors being so closely spaced along the article that periodically varying current of substantially the same phase and frequency when supplied to said inductors simultaneously will heat said zones and will produce a flux field in the space between the inductors to heat an intermediate part of the article lying between said zones substantially as intensely as the zones are heated, connecting the inductors to separate circuits, the said circuits being adapted to supply inducing current of the same phase to both of the inductors, changing capacity in said circuits to shift a flux field being produced by current in one inductor sufficiently out of phase relative to a flux field being produced by current in the other inductor to substantially

cancel the flux field in the space between the inductors to substantially eliminate a generation of heating current in the aforesaid intermediate part of the article, and timing the supply of current to one inductor relative to that being supplied to the other to provide an interval in which substantial heating current is generated in the intermediate part to produce a predetermined heating in said part, the heating in said part being substantially less than the heating in one of said zones.

FRANCIS S. DENNEEN.
WILLIAM C. DUNN.