Feb. 13, 1951 H. A. STRICKLAND, JR. 2,541,124

INDUCTION HEATING APPARATUS FOR HEATING SURFACE APERTURED WORKPIECES

Filed Jan. 25, 1947

FIG. 1

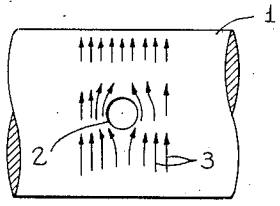


FIG. 2

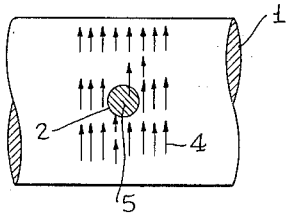


FIG. 3

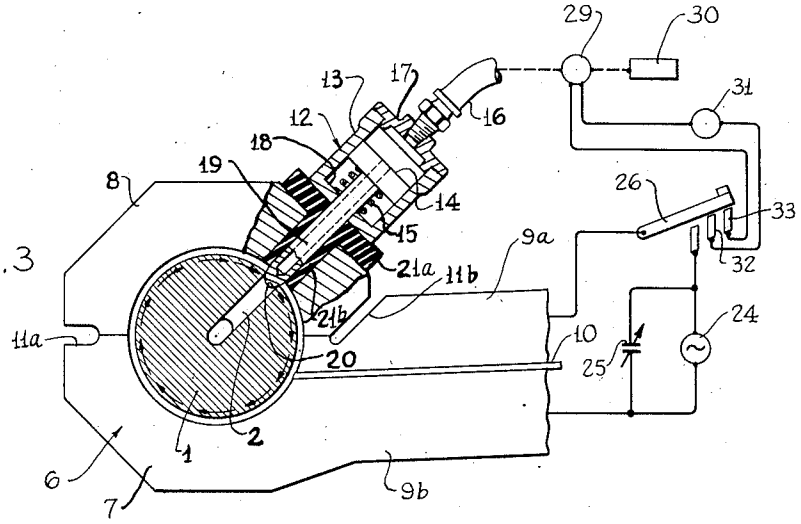


FIG. 4

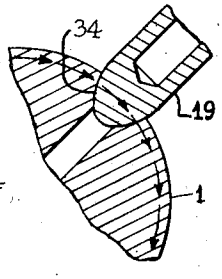
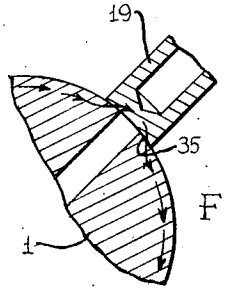


FIG. 5



INVENTOR

HAROLD A. STRICKLAND JR.

BY Maurice A. Crepps

ATTORNEY

Patented Feb. 13, 1951

2,541,124

UNITED STATES PATENT OFFICE

2,541,124

INDUCTION HEATING APPARATUS FOR HEATING SURFACE APERTURED WORKPIECES

Harold A. Strickland, Jr., Detroit, Mich., assignor, by mesne assignments, to The Ohio Crankshaft Company, Cleveland, Ohio, a corporation of Ohio

Application January 25, 1947, Serial No. 724,373

6 Claims. (Cl. 219—47)

1

This invention relates to induction heating apparatus, with specific application to arrangements for preventing overheating around the edges of openings in the workpiece.

In inductive heating operations as applied to workpieces, such as shafts, of cylindrical contour and having radial oil ducts therein for lubrication and other purposes, a problem of heating exists in that due to the opening the circulating current induced by the heating coil is unevenly distributed about the opening with greater density at the edge, so that in the heating interval the heat supplied at the opening edge is excessive and burning results. To overcome this difficulty and insure a uniformity in the heating effect, it has been the practice in the past to insert a metal plug in the duct extending to the surface of the workpiece to provide a surface flux path and prevent the increase of current density at the edges of the duct opening. A difficulty with this method of handling the problem is that in addition to the very laborious problem of inserting plugs, particularly where the holes are small, the metal plugs become solidly fixed in the duct, and are particularly difficult to remove after the heating operation, especially from blind holes.

A primary object of the present invention is to provide a plug for a duct opening in a workpiece subject to inductive heating which may be readily applied and removed, especially without labor.

Related objects pertain to the provision of means for permitting automatic closure of the duct opening during the heating period, for insuring adequate metal contact at the edge of the opening with the plug element, and for facilitating effective engagement of the plug element with duct openings of different dimensions.

Reference is made to the following specification for description of embodiments of the invention which may be preferred and to the accompanying drawings, in which:

Figure 1 is a view illustrative of the flow of magnetic flux in a cylindrical shaft having an oil duct therein, showing the flux distribution at the duct opening;

Figure 2 is a view illustrating the flux distribution where a plug is employed to close the duct opening;

Figure 3 is an elevation of the heating element with parts in section, illustrative of the automatic plug element;

Figure 4 is a detail showing in section a structure insuring adequate metal contact between the workpiece and the plug; and

2

Figure 5 is a view illustrative of a modification of the plug element.

When electrical energy is supplied a coil surrounding a metal workpiece, magnetic flux traverses the metal of the workpiece in a flow varying with the variation in the direction of flow of current in the coil. In Figures 1 and 2 is illustrated the current resulting from this flux flow for a given instantaneous direction of current flow in the coil at a section of the workpiece surface at which an aperture or indentation is formed. For the purpose of illustration the workpiece is assumed to be a metal shaft 1 having an oil hole or duct 2, the magnetic flux lines being indicated by the arrows 3 in Figure 1, and arrows 4 in Figure 2. Inspection of Figure 1 makes clear the fact that due to the inability of the current to flow across the opening, it tends to concentrate on opposite edges of the opening. As a result the heating effect, which is a function of current density squared, is increased in these areas so that for a given desired heating temperature in the shaft as a whole there is an overheating at the duct edges which brings about burning or fusion. Figure 2 illustrates the result obtained by inserting a metal plug 5 in the opening 2, thus providing a path for the current substantially equivalent to that of the metal of the shaft, whereby the current density at the opening edges is kept substantially uniform and overheating is prevented.

In Figure 3 is illustrated apparatus through which metallic bridging of the duct opening is readily brought about during the heating operation of the shaft. The shaft 1 is shown as positioned in the central opening made by an induction heating coil 6. This coil is of the usual one turn, having a lower segment 7 and an upper segment 8 fixed together by any appropriate means to establish electrical continuity between the terminals 9a and 9b in extension of the ends of the coil turn 6. These terminals are separated by an insulating plate 10 to permit close contiguity of the terminals for development of proximity effect. Preferably transverse recesses 11a and 11b are formed in the coil turn to force the current close to the inner surface of the enclosing wall of the turn, thus bringing about approximate uniformity of current flow about the shaft.

Adapted for operative placement on the section 8 of the coil turn is a power unit 12 having a cylindrical drum 13 adapted to receive a piston 14 movable against a coil spring 15 through action of air pressure. Alternately, a liquid, as water,

may be used to increase the cooling action. The air source transmits air through the conduit 16 and drum cap 17 to the drum interior between the cap and piston head 14. Extending through the base 18 of the drum is a plug 19 having a rounded convex end 20 preferably approaching an elliptical or parabolic contour and hollowed for cooling purposes. This unit is secured to the section 8 of the coil turn by attachment of the base 18 of the drum to an insulator plate 21*a*, which in turn is integral with an insulation tube 21*b* extending through the metal of the turn radially to the inner wall of the same. The insulator elements 21*a* and 21*b* are apertured in alignment with the plug of the piston and provide a seat for plug reciprocation. While not essential, it is desirable in many uses to make the aperture of the insulator elements 21*a* and 21*b*, as well as the opening through drum base 18, oversize with reference to the plug diameter to permit automatic adjustment to plug-shaft opening misalignment.

The power source for the inductor 6 is indicated at 24 in Figure 3 in conjunction with a variable capacitor 25 for power factor control and a main contactor switch 26 for initiating power flow. An electromagnet-operated valve 29 is inserted in the air conduit 16 between the power unit 12 and the source of air supply 30 for controlling the flow of air to the power unit 12. This electromagnet may be operated through a transformer or branch circuit connection to the power circuit of the inductor or may be energized from a separate source of power 31 as shown, the circuit including contacts 32 and 33 engageable by the main contactor switch 26. This switch may close both the power circuit and the valve control circuit simultaneously, or, in the event of time lag in the valve circuit, the contacts 32 and 33 of the valve control circuit may be closed before the main power circuit is closed so as to insure engagement of the plug tip in the workpiece opening at the time of heat application to the workpiece.

The operation of the unit as shown in Figure 3 consists in an inward movement of the plug 19 against the resilient action of spring 15 when pressure is supplied the drum through the conduit 16. This pressure is applied only when the main contactor switch 26 of the circuit controlling flow of current to the terminals 9*a* and 9*b* of the coil 6 is closed. Since the opening of the oil duct is in approximate alignment with the line of movement of the plug, the head 20 engages the external edge of the opening and, because of its curved surface and the lose mounting of the plug, it accommodates itself to the opening edge and forms a metal bridge across the same. At the conclusion of the heating period the power circuit is opened and simultaneously pressure is released in the plunger and the spring moves the plug away from the oil duct opening.

To facilitate appropriate contact between the plug end and the duct opening edge, this edge may be chamfered either to produce a conical flare or a surface curved similarly to the plug end, as suggested by the structure indicated by numeral 34 in Figure 4. This construction not only gives a leeway of adjustment, but also insures increased area of contact between the plug and the shaft to avoid any possibility of excessive reluctance in this region.

An alternative means of bridging the duct opening is shown in Figure 5. In this figure instead of forming the plug end in a convex curvature,

the end is made concave, as shown at 35, so as to fit the external curvature of the shaft in the region of the same adjacent the edge of the duct opening. An advantage of this construction resides in its adaptability for heating operations where the oil openings are apt to be measurably out of alignment with the direction of movement of the plug element. Since the end of the plug is oversized in relation to the diameter of the duct opening, substantial misalignment is permissible. Further, this modification insures substantial metal contact in the region of the duct so as to prevent excessive resistance. While the showing of this figure indicates that the curvature of the shaft and the plug end are the same, in practical uses there may be some variation between these surfaces permitting use of the equipment for shafts of different diameters. For example, for workpieces of curvature other than that shown in Figure 5, it is apparent that contact will be made in the region of the edges irrespective of these curvature differences. For this purpose the tip surface of the plug may be substantially flat. Obviously, where the workpiece has a flat surface there will be no particular problem of providing a flush contact between the workpiece and plug end.

Modifications of the details of this disclosure may be made in accommodation to the special problems of application, and hence no limitation is implied by the apparatus described other than may be required in the claims as hereto appended.

What is claimed is:

1. An induction heating coil adapted to have high-frequency currents circulated therein for heating a workpiece having a duct therein, said coil overlying said duct when in heating position, a movable plug reciprocable in a radial opening in said coil and having an electrically-conductive end adapted to contact and form an electrical closure for the outer end of the duct, and means to move and hold said plug in contact with said workpiece coincident with the flow of heating current through said coil.

2. An induction heating coil adapted to have high-frequency currents circulated therein for heating a workpiece having a duct therein, said coil overlying said duct when in heating position, a plug reciprocably supported in a radial opening in said coil and having an electrically-conductive end adapted to form a closure for the outer end of said duct, and means to move said plug inwardly and hold said plug in engagement with said workpiece generally coincident with the flow of heating current through said coil, said plug end having a convex surface permitting minor misalignment of the duct and plug axis.

3. An induction heating coil adapted to have high-frequency currents circulated therein for heating a workpiece having a duct therein, said coil overlying said duct when in heating position, a plug reciprocably supported in a radial opening in said coil and having an electrically-conductive end adapted to form a closure for the outer end of said duct, and means to move said plug inwardly and hold said plug in engagement with said workpiece generally coincident with the flow of heating current through said coil, said plug end having a convex surface, said plug loosely fitting in said opening thereby permitting minor misalignment of the duct and plug axis.

4. An induction heating coil adapted to have high-frequency currents circulated therein for heating a workpiece having a duct therein, said coil overlying said duct when in heating position,

a plug reciprocably supported in a radial opening in said coil and having an electrically-conductive end adapted to form a closure for the outer end of said duct, and means to move said plug inwardly and hold said plug in engagement with said workpiece generally coincident with the flow of heating current through said coil, said plug having an end greater in diameter than said duct and adapted to engage the workpiece adjacent the duct and possessing a curvature substantially identical to that of the workpiece adjacent said duct.

5. A high-frequency, induction-heating coil adapted for inducing high-frequency currents in and heating a workpiece having a recess in the surface to be heated, said coil overlying said recess when in heating position, a member movably supported on said coil and having an electrically-conductive portion adapted to contact and form an electrical closure for the outer end of said recess and means to move said portion into contact with said workpiece.

6. An induction-heating coil adapted to have high-frequency currents circulated therein for heating a workpiece having a duct therein, said coil overlying said duct when in heating position, a movable plug reciprocable in a radial opening in said coil and having an electrically-conductive end adapted to contact and form an electrical closure for the outer end of the duct and means to move and hold said plug in contact with said workpiece at least during the flow of heating current through said coil.

HAROLD A. STRICKLAND, JR.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,167,798	Denneen et al.	Aug. 1, 1939
2,240,494	Denneen et al.	May 6, 1941