HIGH FREQUENCY INDUCTOR ARRANGEMENT FOR HEATING A NUMBER OF BAR ENDS IN A SOLENOIDAL COIL
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HIGH FREQUENCY INDUCTOR ARRANGEMENT FOR HEATING A NUMBER OF BAR ENDS IN A SOLENOIDAL COIL

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This invention pertains to the art of high-frequency induction heating and, more particularly, to a combination of induction coil, work-handling, and work-mounting means whereby selected relatively narrow portions of elongated workpieces are brought to elevated temperatures for forging operations and the like. The invention further pertains to a method of induction heating by high-frequency inductors wherein a plurality of workpieces are simultaneously heated and each workpiece is passed through an induction coil only once during a complete heating operation.

In the art of high-frequency induction heating a selected portion of a workpiece, it has been the practice to surround the entire body of the workpiece with a solenoidal coil having an aperture of sufficient dimension to contain the body of the workpiece, the length of the coil being determined by the length of the portion of the workpiece intended for heating. In another proposal, the prior art utilized a number of longitudinally aligned workpieces having a number of axially aligned induction coils spaced intervals and each workpiece traveled longitudinally through each heating coil, coming to rest with a designated portion in heating position at each successive induction coil. In this manner, simultaneous heating of a plurality of workpieces accomplished in some measure a reduction in the time necessary for supplying heated workpieces which have reached a desired temperature for whatever purpose desired, for example, forging or the like.

The main disadvantage of the latter described procedure is that each workpiece necessarily travels through each of the induction coils, thus presenting a problem of handling and also necessitating a substantial area within which to practice the invention since the workpieces are positioned in end-to-end relation and the work area is therefore dictated in part by the cumulative lengths of the workpieces undergoing heating.

The main disadvantage of the first described procedure is that only a single workpiece is heated at a time and thus the apparatus is inherently limited to the time required to bring each workpiece individually to a suitable forging temperature or other working temperature and this limitation imposes the overall operation. Although it is possible to reduce this time by providing more than a single coil, said coils being concurrently operated, this expedient is undesirable since the workpieces tend to be nonuniformly heated and furthermore each coil requires a substantial array of magazines, pusher mechanisms, timers and other apparatus, all of which are required incidentals to the usage of each heating coil, thereby achieving an increase of speed but a substantial increase of cost.

Efforts at increasing heating speed by increasing the power applied to the induction coil is workable only within limits since the thermal conductivity of the metal heated is of finite value in permitting the passage of heat from the outer surface of the workpiece to the interior thereof. This factor determines the point at which further power input to the inductor coil is ineffective to increase the heating speed.

The present invention contemplates overcoming of these problems by means of a single induction coil which is capable of concurrently heating a number of workpieces and thereby increasing the rate of producing heated workpieces.

The present invention further contemplates a new and improved high-frequency induction heating equipment wherein a single heating coil is effective for embracing a number of workpieces comprised of metal bars or the like and which requires only a single associated set of magazines, pusher mechanisms, timers, etc. as compared with a plurality of inductor coils each requiring a set of such structure.

The invention further contemplates a high-frequency induction heating equipment providing substantial uniformity of heating of each workpiece, and wherein the space in each coil aperture is filled with the metal workpiece and thereby minimizing the demand for magnetizing current and operating at a favorable power factor.

The invention further contemplates a new and novel method of inductively heating relatively narrow portions of elongated workpieces wherein motion is transmitted from one workpiece to the next by gravity feed. In accordance with the present invention there is provided an improved high-frequency induction heating apparatus. This apparatus comprises a support having an inclined surface for receiving a plurality of elongated workpieces in side-by-side relationship, a solenoid coil having a workpiece receiving opening with a dimension perpendicular to the surface only slightly greater than the diametrical dimension of said workpieces and a dimension parallel to the surface greater than the diametrical dimension of a plurality of the workpieces, and a high frequency power supply for energizing the coil. The opening of the coil is aligned with the surface with the parallel dimension of the coil having substantially the same angle as the inclined surface. There is also provided a stop means on the opposite side of the coil from the inclined surface and aligned with the inclined surface for locating the workpieces in the coil with only the portion of the workpiece to be heated being within the coil opening. The stop means is substantially coterminous with the workpiece receiving opening except for an outlet at the lowermost end of the coil, this outlet has a dimension greater than the diametrical dimension of one of the workpieces and less than the diametrical dimension of a finite number of the workpieces, the finite number being substantially less than the number of workpieces being received by the coil.

A further object of the invention is to produce at a higher rate of speed a number of heated workpieces, each of which achieves a more uniform temperature and more uniformly absorbs a given quantity of heat.

A further object of the invention is to simplify the handling equipment wherein the workpieces are moved by gravity feed, thereby simplifying the handling apparatus.

A still further object of the invention is the provision of a method of induction heating wherein the workpieces are so arranged within the coil so as to increase the efficiency of the induction coil and interbar electrical current is minimized by placement of the workpieces as, for example, bars, in one plane within the solenoid coil.

Further objects of the invention will become apparent from the following description of a specific example embodying the invention and the attached claims when taken in conjunction with the accompanying drawings illustrating the specific described example embodying the invention, and wherein:

FIGURE 1 is an isometric view of the apparatus, and
FIG. 2 is a wiring diagram of the electrical system and motor actuators for movement of the workpieces.

In this embodiment, a magazine 10 having an inclined
support surface 11 supports a number of workpieces A in the form of elongated circular bars which are intended for such bars along a comparatively narrow portion of the length thereof and following such heating the work-piece is then hot forged. The circular bars A tend to roll or slide downwardly and forwardly in the direction of stops 12 which are spaced apart by a sufficient distance to fix the attitude as well as position of the bottommost bar 14. The magazine 10 supports the workpieces vertically on a set of forward legs 15 which are shorter than rear legs 16 by an amount which determines the degree of gravity force transmitted from one bar to the next and assuring their travel in the direction of the arrow indicated on the support surface 11.

The bottommost one of the workpieces 14 is moved endwise by a push rod 17 actuated by motor 18 which can be powered electrically, mechanically, pneumatically or hydraulically. The normal position of the push rod 17 is retracted for engagement with the bottommost one of the stack of workpieces in the magazine 10 and when the motor 18 energizes the push rod 17 inserts the workpiece 14 endwise into a second magazine 19 having a support surface 20 which is also inclined and is of the same degree of inclination as support surface 11 being held thereto by means of a bracket 21' and supported at the opposite end on legs 26' and 23'.

The inclination of support surface 20 causes the bars to roll or slide forwardly in the direction of the solid line arrow indicated on the stack of bars 21' and the bottommost bar 22 after having traversed the full length of the support surface 20 comes to rest against a flange 23 where it is held against further movement and supports the other bars 21' which are at higher elevation. The bottommost bar 22 is at clearance relation with stop flange 24 and is free to move in the direction of the arrow indicated at end 25 of bar 22.

The stack of bars 21', being quite long, have their centers of gravity well within the confines of magazine 19. They require therefore no vertical support at the relatively narrow portions projecting beyond the magazine 19 and within induction heating coil 26. The coil 26 is of multi-turn solenoid construction having a number of turns, each of which encircles the workpiece and the complete coil surrounds the portion of the workpiece intended for heating. There is a space provided between each coil turn and the bar ends for maintaining an electrical insulation. The ends 27 and 28 are then connected to the output terminals of a high-frequency transformer B in a manner common in the induction heating art.

Each turn of the coil 26 encompasses all of the projected ends of the workpieces, i.e. the bars 21', 22 and the coils are stacked so that their cumulative width encompasses the portions of the bars intended for heating. This immediately creates the advantage of a single solenoidal coil 26 concurrently heating a number of workpieces or bars and requiring no more than the usual ancillary handling equipment necessary for heating a single workpiece.

It is necessary to provide enough power from the heating source to heat the bar portions within a relatively short time. The arrangement is inherently efficient since the space within the coil aperture 29 is filled with bars thereby producing a condition which minimizes the demand for magnetizing current and affects a satisfactory power factor.

The projected ends of the workbars 21', 22 are in line-to-line contact and are all disposed coplanar in order to maintain only negligible current flow between successive bars through their line of contact. There is only an insignificant magnitude of induced voltage longitudinally within the bars to cause undesirable current flow between successive bars so that heating and sparking which could mar the bar surface is minimized. Although the uppermost bar and lowermost bar in the magazine 19 receive the greatest power input, each bar, traversing the same path, receives the same total heating effect and thereby attains the same narrow portion of the length thereof and following such heating the work-piece is then hot forged. The circular bars A tend to roll or slide downwardly and forwardly in the direction of stops 12 which are spaced apart by a sufficient distance to fix the attitude as well as position of the bottommost bar 14. The magazine 10 supports the workpieces vertically on a set of forward legs 15 which are shorter than rear legs 16 by an amount which determines the degree of gravity force transmitted from one bar to the next and assuring their travel in the direction of the arrow indicated on the support surface 11.

At the end of each prescribed time interval, a timer 33 energizes a circuit having a conductor 34 actuating a solenoid 35 which closes switches 36 and connects conductor 34a with conductor 37 which in turn energizes solenoid 38. The solenoid 38 urges the spool 39 rightwardly against the resilience of spring 39' and thereby communicates pressure fluid from line 40 to line 41 displacing the push rod 31 leftwardly until the plunger contacts limit switch 42 which is responsive to extending movement of the push rod and breaks the circuit including conductors 34a, 43 and thereby deenergizes solenoid 35 opening switches 36, and deenergizing solenoid 38. The spring 39' then biases the spool 39 leftwardly communicating the pressure line 40 to line 45 and line 41 to exhaust thereby retracting the push rod 31 until contact is made with limit switch 46 which is closed temporarily and only by retractive movement of the rod 31.

The switch 46 when closed energizes through conductors 46a a solenoid 49 closing switches 50 which in turn energizes solenoid 51 through conductor 52 and moving the spool 53 rightwardly against the resilience of spring 54 and communicating fluid pressure from line 55 to the right hand side of piston 56 through line 57 and communicating the left hand side through line 58 to exhaust. The piston 56 moves to the left until push rod 17 engages the limit switch 60 responsive only to extending movement of the push rod 17 and breaks the circuit through conductors 60a deenergizing solenoids 49 and 51 and allowing the spring 54 to bias spool 53 leftwardly communicating fluid pressure from the pressure line 55 to the left hand side of the piston and the right hand side of the piston to exhaust, thereby retracting the push rod 17. A push button 61 can be used for overriding the timer 33 by manual operation for removal of one or all the rods from the coil 26.

The stroke length of push rod 31 is sufficient to fully displace the bottommost rod 22 from its heated position. The rod 22 when displaced from the inductor coil causes the other rods 21 to move downwardly and makes room for the next incoming rod 14 from magazine 19 and which starts at the top of the magazine 19 gradually working its way down to the rod 22 position.

In contrast with the previously followed induction heating process, the one described herein requires only one passage of the workpiece or bar through the heating coil, this occurring at the end of the heating period. Also, since a number of bars are concurrently heated, the time interval between the successive production of a heated bar is reduced by a factor of n times, where n is the number of bars being concurrently heated by the inductor coil. Thus, if the total heating time is six minutes and six rods are concurrently heated, the rate of supplying heated rods is six minutes/six rods concurrently heated or one rod per minute can be supplied by the apparatus in fully heated condition.

The heating time will, of course, depend upon the power supplied from the transformer B connecting with output terminals 27 and 28 respectively of the coil 26. The frequency and power provided the coil 26 is in accordance with the heat conductivity, size, temperature and time of heating required of the workpieces. Since each bar is at the same position and for identical time periods then assuming the power input to remain the same in the coil 26, each bar when ejected from the coil will be at the same temperature and the same portion thereof will have absorbed an equal amount of heat as the corresponding portion of any of the other preceding bars.

Obviously, the apparatus described can be readily adjusted to various heating times, various diameter and length of bars and portions intended for heating, as for example by merely replacing the heating coil 26 with a different heating coil or by adjusting the power and fre-
frequency from the power source to the terminals of the induction coil.

Where the workpiece or rod is not of so great length and the center of gravity or rod is disposed within the coil 26 so that support is needed internally of the coil, the incline area of magazine 19 may extend within the coil 26 and is of an insulating composition such as ceramic material or the like, the specific composition of which is not part of the present invention.

It is obvious that operation subsequent to the heating may consist of forging, quenching, bending, or any other suitable operation requiring heating of the workpiece prior to its operation.

The invention has been described with particular reference to a preferred apparatus and method embodiment. It will be obvious that modifications and alterations will occur to others upon a reading and understanding of the specification and it is my intention to include all such modifications insofar as they come within the scope of the appended claims.

Having thus described my invention, I claim:

1. In high frequency induction heating equipment, a support having an inclined surface for receiving a plurality of elongated workpieces in side-by-side relationship, a solenoid coil having a workpiece receiving opening with a dimension perpendicular to said surface only slightly greater than the diametrical dimension of said workpieces and a dimension parallel to said surface greater than the diametrical dimension of a plurality of said workpieces, a high frequency power supply for energizing said coil, the opening of said coil being aligned with said surface with the parallel dimension of said coil having substantially the same angle as said inclined surface, stop means on the opposite side of said coil from said inclined surface and aligned with said inclined surface for locating said workpieces in said coil with only the portion of said workpieces to be heated within said coil opening, said stop means being substantially coterminus with said workpiece receiving opening except for an outlet at the lowermost end of said coil, said outlet having a dimension greater than the diametrical dimension of one of said workpieces and less than the diametrical dimension of a finite number of said workpieces, said finite number being substantially less than the number of workpieces being received by said coil.

2. The high frequency induction heating equipment as defined in claim 1 wherein said inclined surface is constructed of a substantially non-conductive material and said surface extends into said workpiece receiving opening.

3. The high frequency induction heating equipment as defined in claim 1 wherein there is included first means for pushing the lowermost workpiece on said inclined surface through said outlet, second means for pushing a workpiece on said surface into the uppermost portion of said workpiece receiving opening and sequencing means for actuating said first means and then said second means after said lowermost workpiece has been properly heated by said coil.

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