

[54] APPARATUS AND METHOD OF
INDUCTIVELY HEATING SPACED
SURFACES ON AN ELONGATED
WORKPIECE

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266/4 E

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219/10.57, 10.67, 10.69, 10.71, 10.73; 266/4
E, 5 E

[56]

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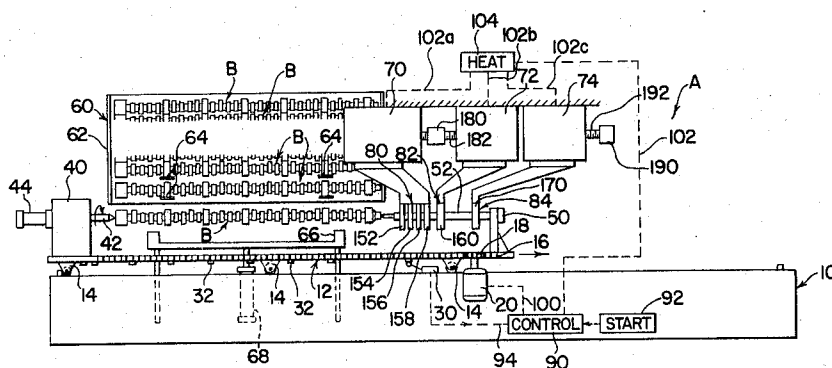
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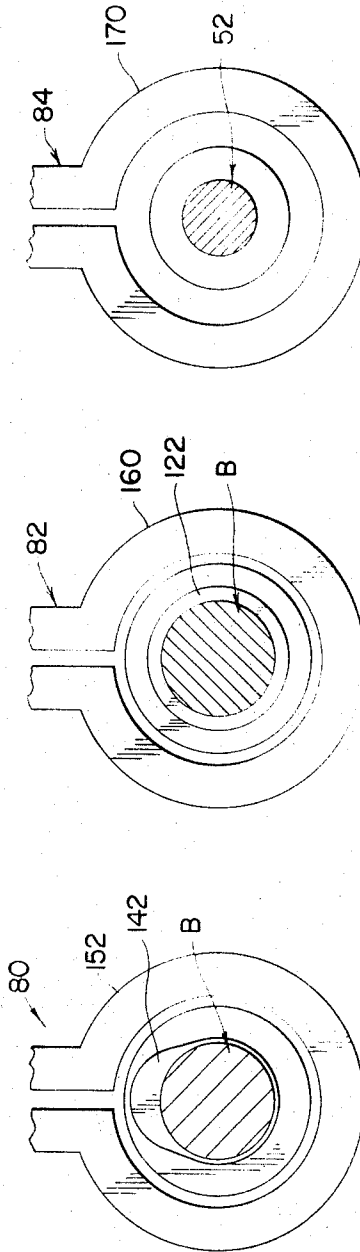
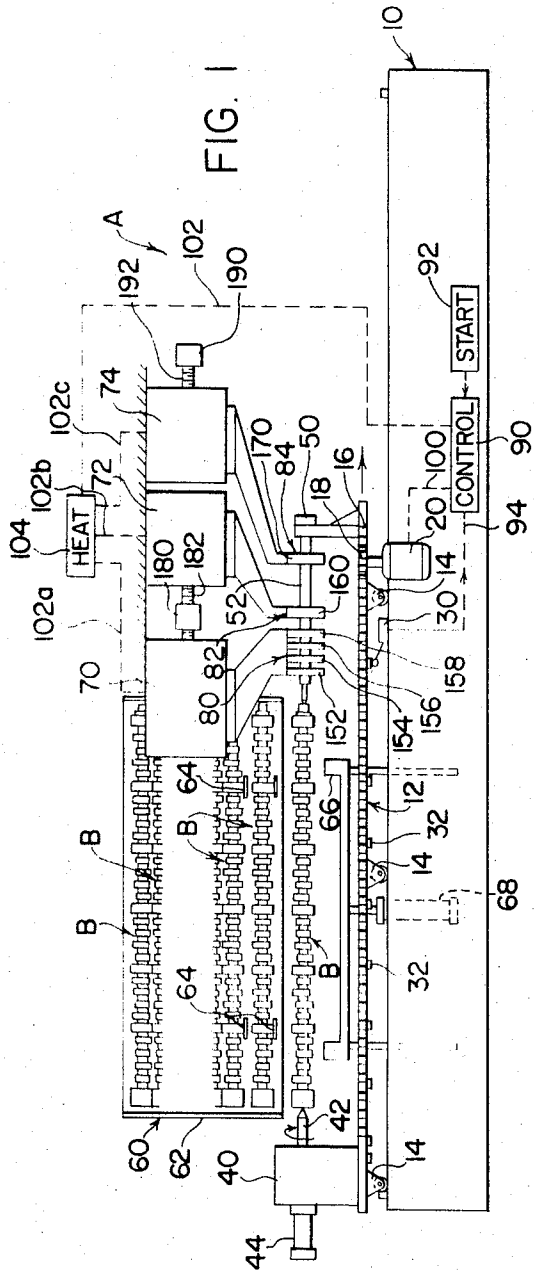
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ABSTRACT

There is provided an apparatus and method of heating a number of axially spaced, wear surfaces on a camshaft preparatory to quench hardening the surfaces. At least two fixed inductors surrounding the camshaft simultaneously heat two or more axially spaced surfaces. The workpiece is moved successively through the two inductors until all of the wear surfaces have been inductively heated for quench hardening.

14 Claims, 12 Drawing Figures





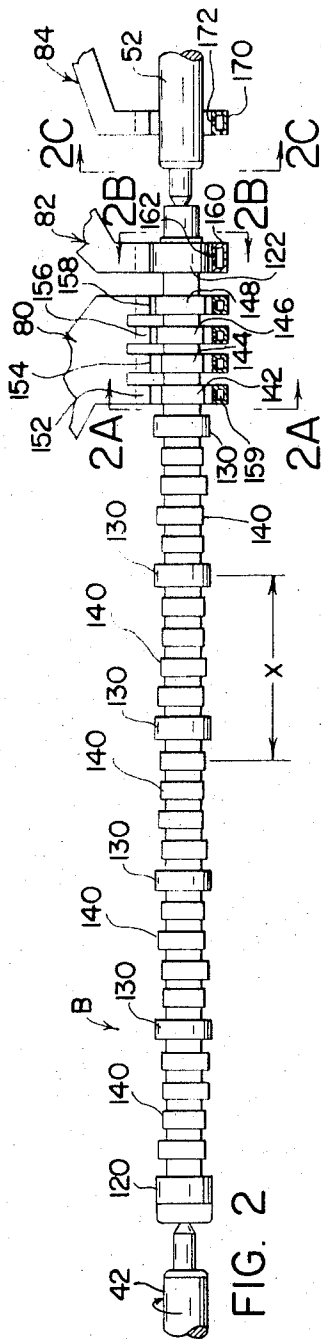


FIG. 2

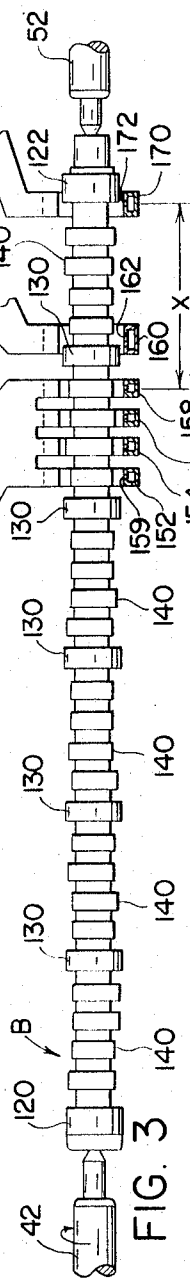


FIG. 3

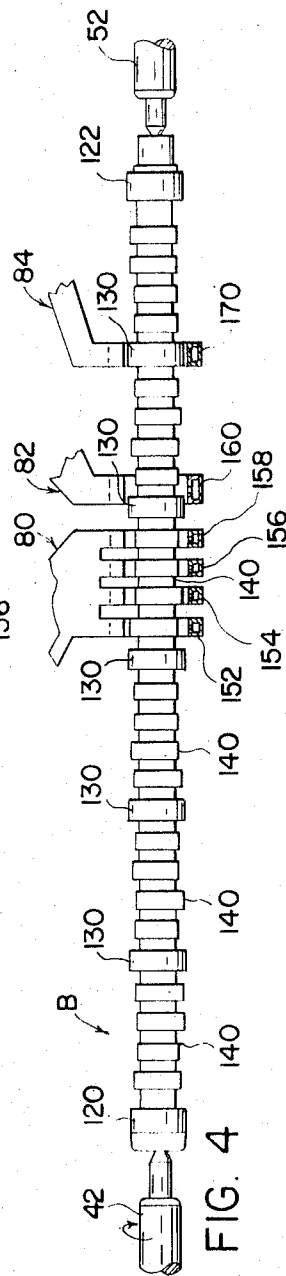


FIG. 4

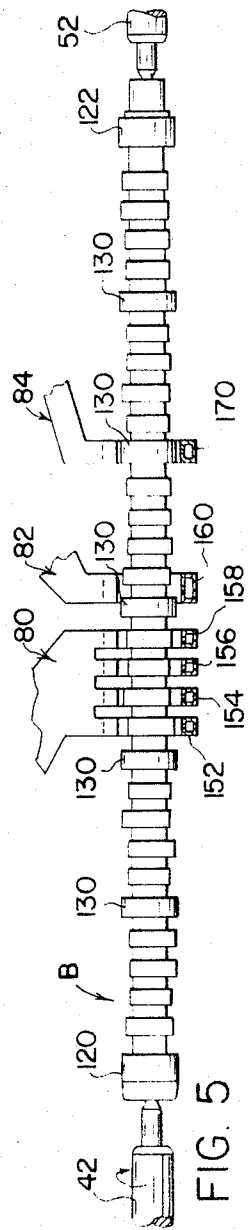
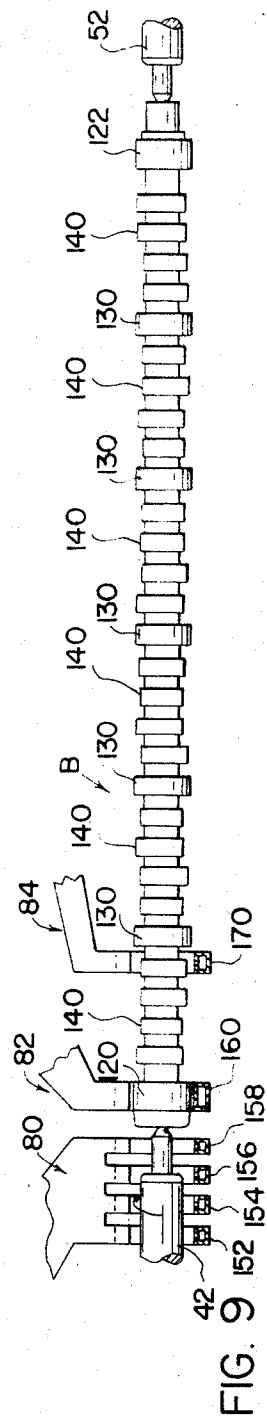
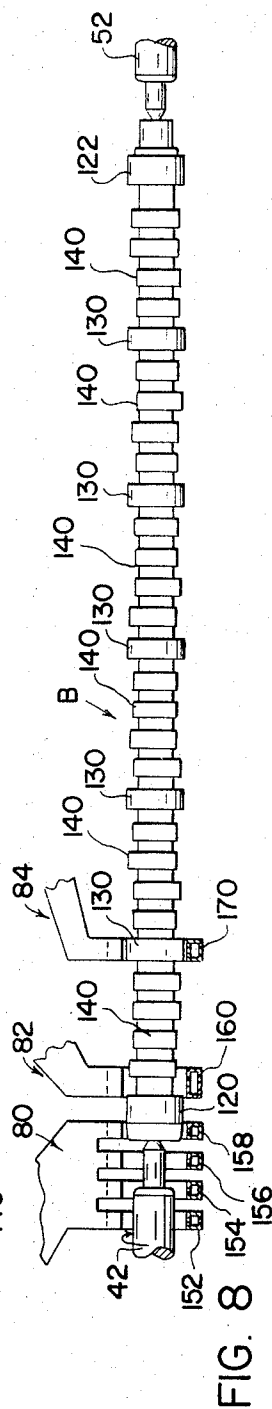
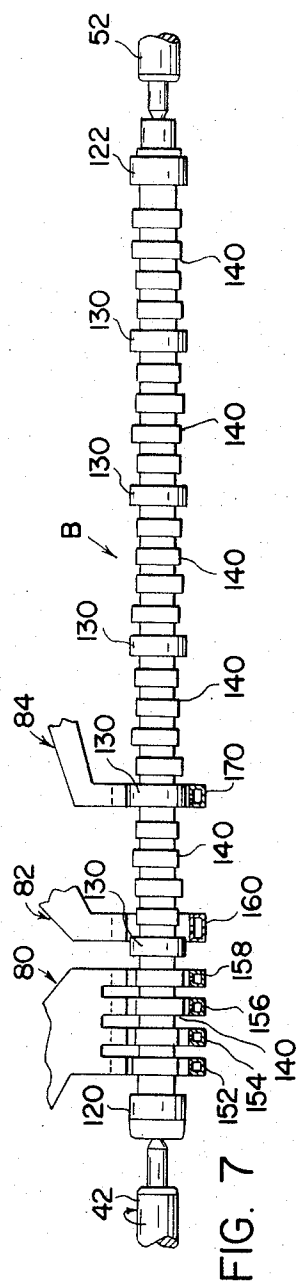
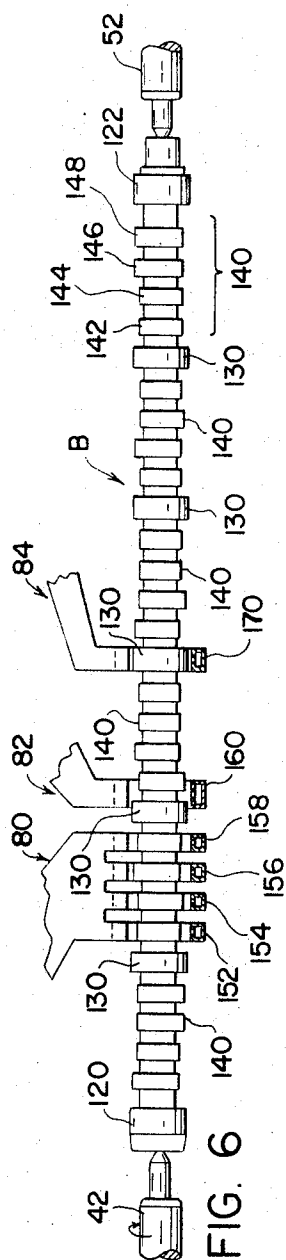


FIG. 5



APPARATUS AND METHOD OF INDUCTIVELY HEATING SPACED SURFACES ON AN ELONGATED WORKPIECE

The present invention relates to the art of induction heating and more particularly to an apparatus and method of inductively heating spaced surfaces on an elongated workpiece, such as a camshaft for a motor vehicle.

The invention is particularly applicable for heating the various wear surfaces, such as cam lobes and bearing surfaces, axially spaced along a camshaft for an internal combustion engine, and it will be described with particular reference thereto; however, the invention is much broader and may be used for processing various elongated workpieces having a series of finite, axially spaced surfaces to be inductively heated preparatory to quench hardening.

Camshafts for internal combustion engines generally include a succession of cam lobes and support bearings, each of which presents wear surfaces that must be hardened before used in an internal combustion engine. The most successful manner of hardening these various surfaces on a camshaft is by positioning an inductor around one of the surfaces and energizing the inductor by high frequency current. This causes induction heating of the surface. Thereafter, the surface is quench hardened by either directing a coolant onto the heated surface or plunging the camshaft into a bath of liquid coolant.

Induction heating of the axially spaced surfaces on a camshaft has generally been accomplished by one of two methods. In accordance with the first method, a special inductor unit is built for a particular camshaft and includes inductor elements which correspond with each of the spaced surfaces to be heated. The camshaft is then rotated and all the spaced surfaces are simultaneously heated by induction. As the number of surfaces is increased, this system or method becomes somewhat prohibitive because the total power required becomes too high for practical and economically available equipment. For instance, in some common camshafts this method may require power in the range of 1,000 kilowatts. In addition, the various types of surfaces may require different heating energy which could not be easily adjusted when a single inductor unit was used. Consequently, all of the surfaces were heated by an energy level which was required for the most demanding surfaces. This reduced the efficiency of the heating operation. Also, each type of camshaft required its own coil or inductor unit. Consequently, the method was applicable only for high production camshafts and was not suitable for a combination of high production and low production camshafts or a series of low production camshafts.

To overcome the disadvantages of the high power requirements and special inductor units required by the method discussed above, a second method of heating the spaced surfaces on a camshaft was developed. This method included the use of a single inductor for heating a single wear surface at one time. The lobes were heated successively in a given heating device. After the lobes were processed, the intermediate bearings were heated in a separate heating device; and, lastly, a third heating device was used to heat the end bearings of the camshaft. In between each heating operation, the camshaft was either plunged into a coolant or sprayed by a coolant at the induction heating station. This process

required a relatively small amount of power as only one surface was being heated at a given time. This system could be used for low production camshafts because the number of lobes and bearings could vary without requiring additional heating equipment or special inductor units. However, this system introduced a substantial amount of handling between heating operations. Consequently, this type of system was not too successful for camshafts, other than very low production camshafts. High production camshafts clearly were not appropriate for processing by this type of procedure.

The present invention relates to an apparatus and method for inductively heating spaced surfaces on an elongated workpiece, such as a camshaft, which overcomes the difficulties experienced in the two methods mentioned above.

In accordance with the invention, there is provided an apparatus for inductively heating surfaces axially spaced along an elongated workpiece preparatory to quench hardening, wherein the surfaces include alternate first and second surfaces. The device includes first and second axially spaced inductors surrounding the workpiece, and means for causing relative axial movement between the workpiece and the inductor successively from a first position to a second position and then to a third position. In each of the positions the first inductor surrounds one of the first surfaces and the second inductor surrounds one of the second surfaces. There is also included means for energizing the first and second inductors in each of the three positions whereby one of the first surfaces and one of the second surfaces are simultaneously inductively heated by the two inductors. This process is continued until all of the surfaces are inductively heated. The first surfaces may each be a group of lobes which requires a particular type of inductor. The second surfaces may be the intermediate bearings which require a different type of inductor. In most camshafts these lobes and intermediate bearings have a fixed axial spacing; therefore, when a group of lobes are being inductively heated by the first inductor, an intermediate bearing may be heated by the second inductor. As the length of the camshaft is increased, generally the spacing between the lobes and the intermediate bearings remains constant and only the number of lobes and bearings is increased. Consequently, the same axial spacing may be maintained between the two inductors and they may be advanced along the length of the camshaft until each of the surfaces has been inductively heated and quench hardened.

In accordance with another aspect of the invention, the device defined above may include a third inductor which is fixed with respect to the second and third inductors. This third inductor is used intermittently for inductively heating third surfaces along the camshaft. These third surfaces may be the two end or main bearings of the camshaft. In this apparatus, the camshaft is stepped along its length through the three inductors. In certain positions the lobes and intermediate bearings are simultaneously heated. In other positions, the end bearings are heated by the third inductor. If the relative spacing between the intermediate bearings, end bearings and lobes are changed, the inductors can be adjusted in an axial direction to accomplish proper sequencing of heating. For a given crankshaft, the induc-

tor spacing need not be changed during processing of each camshaft.

In accordance with another aspect of the present invention, there is provided a method of inductively heating a series of circumferentially extending, axially spaced wear surfaces on a camshaft preparatory to quench hardening, which method comprises the steps of providing first and second inductors spaced axially of the camshaft and surrounding the camshaft, simultaneously locating the first inductor in coupling relationship with a first of the surfaces and the second inductor in coupling relationship with a second of the surfaces, energizing the inductors by alternating current whereby the first and second surfaces are inductively heated, then simultaneously locating the first inductor in coupling relationship with a third of the surfaces and the second inductor in coupling relationship with a fourth of the surfaces, and again energizing the first and second inductors by an alternating current whereby the third and fourth surfaces are inductively heated.

The present invention allows relatively low power to be used in the heating operation without individual heating of single surfaces along the camshaft. The camshaft itself is handled only once to load the workpiece into the heating device, which is then automatically controlled to successively heat and quench the axially spaced wear surfaces along the length of the camshaft. Different length camshafts can be processed in the present device by providing additional controls to increase or decrease the number of heating positions along the length of the workpiece. This reduces the required number of inductors and decreases the processing time irrespective of the production quantity of the particular camshaft.

The primary object of the present invention is the provision of a method and apparatus for inductively heating axially spaced surfaces on an elongated workpiece preparatory to quench hardening, which method and apparatus simultaneously heat two or more of the spaced surfaces and then repeats the heating operation along the length of the workpiece until a majority of the surfaces have been heated.

Another object of the present invention is the provision of a method and apparatus for inductively heating axially spaced surfaces on an elongated workpiece preparatory to quench hardening, which method and apparatus use at least two spaced inductors and means for progressively moving the workpiece through the inductors for successively heating different sets of the surfaces.

These and other objects and advantages will become apparent from the following description taken together with the accompanying drawings in which:

FIG. 1 is a side elevational view showing, somewhat schematically, the preferred embodiment of the present invention;

FIG. 2 is an enlarged view showing a portion of the apparatus as disclosed in FIG. 1;

FIG. 2A is an enlarged, partial cross-sectional view taken generally along line 2a-2a of FIG. 2;

FIG. 2B is an enlarged, partial cross-sectional view taken generally along line 2b-2b of FIG. 2;

FIG. 2C is an enlarged, partial cross-sectional view taken generally along line 2c-2c of FIG. 2; and,

FIGS. 3-9 are views similar to FIG. 2 illustrating processing steps of the illustrated embodiment of the present invention.

Referring now the drawings wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only and not for the purpose of limiting same, FIG. 1 shows, schematically, an apparatus A for heating a series of axially spaced wear surfaces on an elongated workpiece, such as camshaft B. In accordance with the illustrated embodiment of the invention, apparatus A includes a support bed 10 along which a carriage 12 reciprocates in a direction axial of the workpiece B on a series of spaced wheels 14 received by appropriate ways or rails, not shown. The carriage includes a rack 16 which engages a pinion 18 driven by a reversible motor 20 secured onto the bed 10. Rotation of the motor causes reciprocation of the carriage 12 with respect to bed 10. A limit switch 30, secured onto bed 10, engages a series of cams 32 on carriage 12 for a purpose to be explained later. At the left end of bed 10 there is provided a head stock 40 having an internal rotation drive mechanism which rotates a center 42 that is moved axially by a cylinder 44. At the opposite end of the bed there is provided a tail stock 50 having a fixed center 52. The camshaft B is positioned between centers 42, 52 by an appropriate mechanism which is schematically illustrated as loading device 60. It is appreciated that various other loading devices could be used. Indeed, a camshaft B could be positioned between the centers manually. Loading device 60 includes an inclined platform 62 having retractable stops 64 for selectively dropping a camshaft B into a locating nest 66 movable upwardly into a loading position by a cylinder 68. Operation of the loading device is apparent from the drawing. Locating nest 66 is moved upwardly and the lower stops 64 are retracted. This drops a camshaft B into the locating nest 66 so that the center 42 can be moved into engagement with the left end of cam shaft B. This locates the workpiece between this center and the tail stock center 52 for rotation about its longitudinal axis.

In accordance with the illustrated embodiment of the present invention, separate power supplies, shown as transformers 70, 72 and 74 are used to energize, selectively, inductors 80, 82 and 84, respectively. The details of these inductors will be explained later. Transformers 70, 72 and 74 are energized by a control 90 which may take a variety of structural forms and the specific details of this control do not form a part of the present invention. A starting unit 92, which may be a push button or other type of starting arrangement, energizes the control 90 which receives input pulses from line 94 connected to the limit switch 30. Motor 20 is controlled by a line 100 also extending from the control 90. To energize the transformers, there is provided a heat control line 102 which extends to the heat control unit 104 having output lines 102a, 102b and 102c for energizing the different transformers. In operation, the carriage 12 is moved to the right, after starting unit 92 has been initiated, until switch 30 engages one of the cams 32. When the cam is contacted, a signal through line 94 causes a signal in line 100 to stop motor 20 and a signal in line 102 to initiate one or more of the transformers 70, 72, and 74. After the heating operation has taken place and the heated surfaces have been quenched, in a manner to be explained later, control 90 indexes the carriage 12 to the right until limit switch 30 contacts the next cam 32. This repeats the heating operation. Control 90 includes a control arrangement which actuates the transformers to be energized at each

stopped position. This control may be a magnetic tape, punched card or hard wired controlling device.

Referring now to FIGS. 2, 2A, 2B and 2C, the workpiece B includes end bearings 120, 122, intermediate bearings 130 and groups 140 of cam lobes. Each lobe group 140 includes a specific number of individual cam lobes, shown in the preferred embodiment as four cam lobes 142, 144, 146 and 148. Each of the bearings and lobes must be individually heated and quench hardened to produce the necessary wear characteristics. To accomplish this function in accordance with the present invention, the inductor 80 includes four branches 152, 154, 156 and 158 which are adapted to be aligned with the cam lobes 142, 144, 146 and 148, respectively. In this manner, when the inductor 80 is energized by transformer 70 current flows in each of the branches 152-158. This separately and inductively heats the individual cam lobes. The power for heating the four cam lobes is provided by the separate transformer 70. Each of the branches 152-158 is provided with a series of circumferentially spaced apertures 159 through which quenching fluid may pass after the heating operation has terminated. This provides quench hardening of the previously heated cam lobes. Of course, other quenching devices could be used. Inductor 82 includes a single turn 160 for inductively heating the end bearings 120, 122. This inductor includes a plurality of circumferentially spaced apertures 162 for directing quenching liquid against the previously heated end bearings. Inductor 84 includes a single turn inductor 170 for inductively heating the intermediate bearings 130. This inductor has a plurality of circumferentially spaced apertures 172 for the purpose of quenching, as previously described. Although the transformers 70, 72 and 74 are fixed during a particular heating operation, they may be adjusted for accommodating different spacings of the individual axially spaced surfaces. For instance, assuming that the spacing between the last lobe 148 and the second intermediate bearing 130 to the right of this lobe is the distance x , as shown in FIG. 2, the spacing between the turn or branch 158 and single turn inductor 170 should be approximately x , as shown in FIG. 3. In some instances, spacing may be adjusted from one type of camshaft to another. Consequently, an adjusting means is schematically illustrated in FIG. 1. This adjusting mechanism could take a variety of forms; however, in accordance with the illustrated embodiment of the invention, an adjusting means 180 is used to extend or retract a screw 182. This adjusts the spacing between transformers 70, 72. In a like manner, an adjusting means 190 controls a screw 192 for adjusting the position of transformer 74 with respect to transformer 70. These adjustments allow for accommodation of variations in the cam and bearing spacings for different types of cam lobes. However, generally the spacing is uniform in cams for internal combustion engines and spacing adjustment is not needed. In addition, the cams 32 can be adjustably positioned on carriage 12 for the purpose of adjusting the stopping point for the carriage as it moves along bed 10.

The operation of the illustrated embodiment of the invention is shown in FIGS. 2-9. Referring now to FIG. 2, the camshaft B is in a first position. In this position, transformers 70 and 72 are energized to pass an alternating current through inductor 80 and inductor 82.

In this operation, the first group of cam lobes is inductively heated while the end bearing 122 is heated. After the heating operation, transformers 70, 72 are de-energized and a liquid is forced, by known arrangements, through the apertures 159 and 162 to quench the lobes and end bearing. This heating operation is shown in FIGS. 2A and 2B. It is noted that the cam lobe 142 is not actually concentric with respect to the inductor; however, the inductor branches 152-158 must have an opening sufficiently large to allow passage of the workpiece B axially therethrough, as shown in FIG. 3. In this second position, only transformer 70 is energized. It is noted that inductors 82, 84 are not positioned over either intermediate bearings or end bearings; therefore, they do not need to be energized. After the second group of lobes has been heated as shown in FIG. 3, they are quench hardened and carriage 12 is moved to the third position shown in FIG. 4. In this position, transformer 70 and transformer 74 are energized because the inductor 80 is positioned adjacent the third group of lobes and the inductor 84 is positioned in coupling relationship with the first intermediate bearing 130. After the third group of lobes and the first intermediate bearing have been heated while the workpiece is rotating, these heated surfaces are quench hardened. Then the carriage shifts workpiece B successively through the position shown in FIG. 5, FIG. 6 and FIG. 7. In all of these positions, a group of lobes is inductively heated at the same time as an intermediate bearing 130. These figures show the normal processing steps which do not require selective energizing of different transformers. In these operations, the same heating process takes place along the length of the workpiece. Referring now to FIG. 8, only the last intermediate bearing 130 is heated by the inductor 84; therefore, only the transformer 74 is energized. The last heating operation is shown in FIG. 9 wherein the center inductor 82 is positioned in coupling relationship with the end bearing 120. In this position, only transformer 72 is energized for the heating operation. After the process depicted in FIG. 9 has been completed, workpiece B is moved to the left by reversal of motor 20 and into the position shown in FIG. 1 so that the workpiece B may be removed and a subsequent unhardened workpiece inserted by the procedure previously mentioned.

We claim:

1. An induction heating device for inductively heating surfaces axially spaced along an elongated workpiece having a central axis preparatory to quench hardening said surfaces, said surfaces including alternate first and second surfaces spaced axially along said elongated workpiece, first and second axially spaced inductors surrounding said workpiece, means for causing relative axial movement between said workpiece and said inductors successively from a first position to a second position and to a third position, in each of said positions said first inductor surrounding one of said first surfaces and said second inductor surrounding one of said second surfaces, means for rotating said workpiece about said central axis and means for energizing said first and second inductors in each of said positions while said workpiece is rotating whereby one of said first surfaces and one of said second surfaces are simultaneously inductively heated.

2. An induction heating device as defined in claim 1 wherein said first surfaces each includes a number of

separate wear portions extending around said workpiece and said first inductor includes a plurality of inductor elements each matching one of said number of wear portions of a given first surface.

3. An induction heating device as defined in claim 1 wherein said workpiece includes at least one wear surface different from said first and second surfaces and a third inductor surrounding said workpiece and fixed with respect to said first and second inductors and means for positioning said third inductor in coupling relationship with said one wear surface and means for energizing said third inductor.

4. A device as defined in claim 3 wherein said means for energizing said first and second inductor includes a first alternating current transformer connected to said first inductor and a second alternating current transformer connected to said second inductor.

5. A device as defined in claim 4 including means for selectively and individually energizing said first and second transformers.

6. A device as defined in claim 4 wherein said means for energizing said third inductor includes a third alternating current transformer.

7. A device as defined in claim 6 including means for selectively and individually energizing said first, second and third transformers.

8. A device as defined in claim 1 wherein said means for causing relative axial movement includes means for moving said workpiece coaxially with respect to said first and second inductors.

9. A device as defined in claim 8 wherein said workpiece moving means includes control means for successively stopping said workpiece moving means at said first, second and third positions.

10. An induction heating device for inductively heating bearing surfaces axially spaced along an elongated workpiece preparatory to quench hardening said surfaces, said surfaces being arranged in an axially spaced group of similar surfaces each group having a selected number of said similar surfaces and axially spaced individual surfaces, said groups being separated by at least one of said individual surfaces and at least some of said individual surfaces being spaced a predetermined distance from at least some of said groups of surfaces, said device comprising: a first set of fixed inductor means surrounding said workpiece for inductively heating simultaneously said surfaces in one of said groups, an individual fixed inductor surrounding said workpiece and spaced from said set of inductors generally said predetermined distances, means for shifting said workpiece with respect to said set of inductor means and said individual inductor successively with different groups of

surfaces and different individual surfaces aligned with said set of inductor means and said inductor respectively and means for energizing said inductor means and said individual inductors after said workpiece has been shifted.

11. A method of inductively heating a series of circumferentially extending, axially spaced wear surfaces on a camshaft preparatory to quench hardening, said method comprising the steps of:

- a. providing first and second inductors spaced axially of said camshaft and surrounding said camshaft;
- b. simultaneously locating said first inductor in coupling relationship with a first of said surfaces and said second inductor in coupling relationship with a second of said surfaces;
- c. energizing said inductors by an alternating current while said camshaft is rotating whereby said first and second surfaces are inductively heated;
- d. then simultaneously locating said first inductor in coupling relationship with a third of said surfaces and said second inductor in coupling relationship with a fourth of said surfaces; and,
- e. again energizing said first and second inductors by an alternating current while said camshaft is rotating whereby said third and fourth surfaces are inductively heated.

12. A method as defined in claim 11 including the additional step of:

- f. simultaneously locating said first inductor in coupling relationship with a fifth surface and said second inductor in coupling relationship with a sixth surface; and,
- g. again energizing said first and second inductors by an alternating current whereby said fifth and sixth surfaces are inductively heated.

13. A method as defined in claim 12 wherein said first, third and fifth surfaces and said second, fourth and sixth surfaces are located in succession along said camshaft.

14. A method of heating a series of circumferentially extending, axially spaced surfaces on an elongated workpiece, said method includes the steps of:

- a. simultaneously heating inductively at least two of said surfaces while rotating said workpiece;
- b. then simultaneously heating inductively at least two additional surfaces while rotating said workpiece; and,
- c. repeating said simultaneous heating steps and rotation of said workpiece until approximately all of said surfaces have been heated.

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