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APPARATUS AND METHOD FOR HEATING REDUCED PORTIONS OF
ADJACENT WORKPIECES
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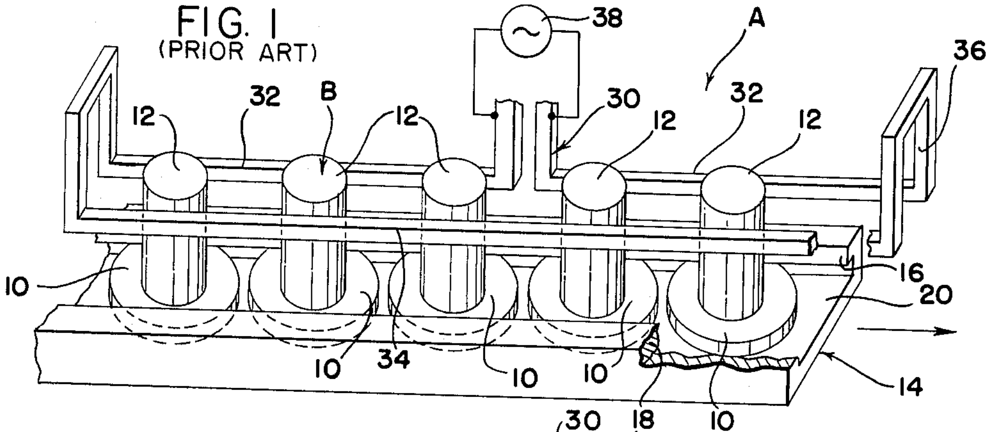
FIG. 1
(PRIOR ART)



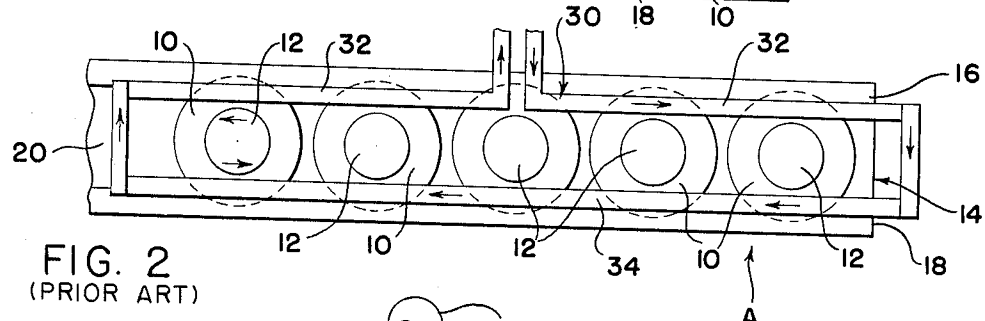


FIG. 2
(PRIOR ART)

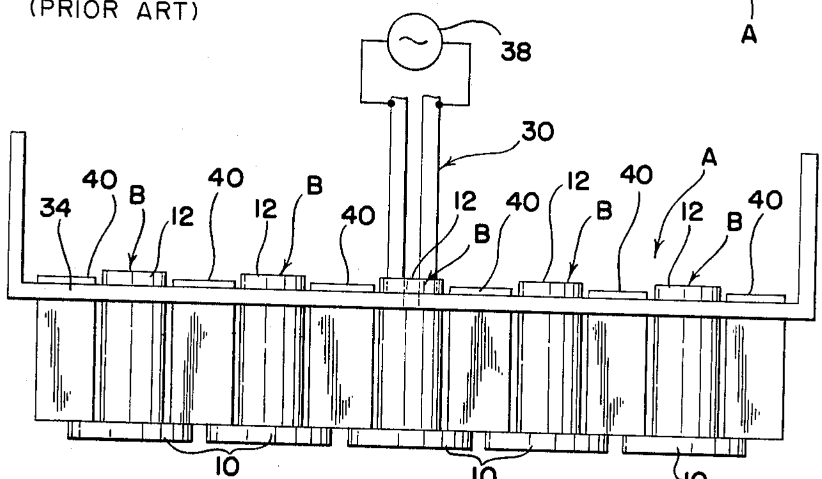


FIG. 3

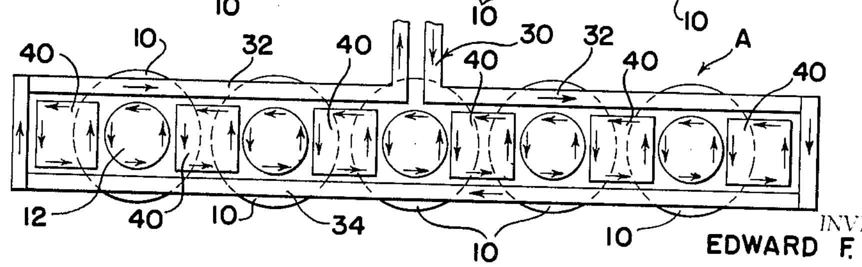


FIG. 4

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APPARATUS AND METHOD FOR HEATING REDUCED PORTIONS OF ADJACENT WORKPIECES

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7 Claims. (Cl. 219—10.69)

The present invention pertains to the art of induction heating and more particularly to an apparatus and method for heating the reduced portions of adjacent workpieces.

The invention is particularly applicable for heating the reduced ends of adjacent flanged workpieces and it will be discussed with particular reference thereto; however, it will be appreciated that the invention has much broader applications and may be used to heat the reduced portions of various shaped workpieces, such as the reduced ends of axle and transmission shafts.

It is often necessary to heat the reduced portions of a workpiece such as the shank of a flanged gear blank for the purpose of annealing or otherwise heat treating the shank. To increase the number of blanks which can be heated in a given time, it has become somewhat common practice to move the gear blanks in side-by-side relationship past an inductor connected to a source of high frequency alternating current. The gear blanks are aligned with the flanges of the blanks abutting each other and the shanks extending in substantially parallel relationship. The inductor may take a variety of configurations; however, generally the inductor is shaped to form a channel having spaced conductors extending along opposite sides of the shanks as the gear blanks move through the inductor channel.

In this manner, the spaced conductors of the inductor induce a voltage or potential difference into the parallel shanks, which potential difference causes current to flow within the shanks. The I^2R heating effect of these currents flowing within the shanks heat the shanks to the desired temperature. The amount of heating is determined by a variety of factors such as the power used in energizing the inductor, the magnetic coupling between the inductor and the shanks, the time the shanks are within the influence of the inductor and the material forming the shanks, to name only a few.

Since the gear blanks have flanges at one end, the parallel shanks are spaced from each other as they move through the channel inductor with the amount of spacing being determined by the difference in the size of the shanks and the flanges. When this spacing is large, certain difficulties have been experienced. For instance, the only portion of the parallel shanks which are heated with any efficiency are the portions immediately adjacent the inductor. In order to heat all portions of the shank uniformly, the shanks must be rotated so that the various portions of the shanks come into proximity with the inductor. The rotation of the gear blanks as they pass through the channel inductor is not always easy and, in some cases, it requires an external means for rotating the blanks. If the blanks are not rotated, the portions of the shanks spaced from the inductor must be heated completely by conduction of heat through the material forming the shanks. This requires a substantial amount of time and, thus, increases the expense of heating the gear blanks.

The large spaces between the parallel shanks leave a substantial portion of the volume within the channel inductor completely vacant. This lowers the magnetic coupling of the inductor and decreases the heating efficiency of the inductor. This lowered efficiency is more pronounced when the volume of the spaces between the

adjacent parallel shanks are quite large, i.e. when the volume of these spaces approaches or exceeds the volume of the shanks within the channel of the heating inductor.

All of these difficulties and others are overcome by the present invention which is directed toward an apparatus and method for heating the reduced portions of adjacent workpieces which apparatus and method increases the efficiency of known procedures of this type and which reduces the need for rotating the workpieces to any great extent as they pass through the channel of the heating inductor.

In accordance with the present invention, there is provided an apparatus for simultaneously heating the aligned reduced portions of a plurality of side-by-side workpieces comprising an inductor having a conductor on each side of the reduced aligned portions and a low resistivity, non-magnetic insert between adjacent reduced portions. In accordance with the invention, the inserts substantially fill the spaces between adjacent reduced portions of the workpieces.

In accordance with another aspect of the present invention, there is provided a method for simultaneously heating the reduced portions of a plurality of workpieces comprising: aligning the workpieces in side-by-side relationship with the reduced portions aligned to produce spaces between adjacent workpieces, substantially filling the spaces between the reduced portions of adjacent workpieces with inserts of low resistivity, non-magnetic material, passing the workpieces between conductors of an inductor, and energizing the inductor with alternating current.

The primary object of the present invention is the provision of an apparatus and method for inductively heating simultaneously the reduced portions of a plurality of workpieces by a surrounding inductor which apparatus and method result in a higher efficiency than was obtainable with known apparatus and procedures.

Another object of the present invention is the provision of an apparatus and method for inductively heating simultaneously the reduced portions of a plurality of workpieces by a surrounding inductor which apparatus and method limits the amount of rotation of the workpieces which is necessary as they move through the inductor.

Yet another object of the present invention is the provision of an apparatus and method for inductively heating simultaneously the reduced portions of a plurality of workpieces by a surrounding inductor which apparatus and method includes the provision of a low resistivity insert between adjacent workpieces and in the space caused by the reduced portions.

A further object of the present invention is the provision of an apparatus and method for inductively heating simultaneously the reduced portions of a plurality of workpieces by a surrounding inductor which apparatus and method prevents substantial vacant volume within the volume defined by the inductor.

These and other objects and advantages will become apparent from the following description used to illustrate the preferred embodiment of the invention as read in connection with the accompanying drawings in which:

FIGURE 1 is a pictorial, partially cut away view showing somewhat schematically the prior art to which the present invention is directed;

FIGURE 2 is a top plan view of the prior art shown in FIGURE 1;

FIGURE 3 is a side elevational view showing, somewhat schematically, the preferred embodiment of the present invention; and,

FIGURE 4 is a top plan view showing the operating characteristics of the preferred embodiment of the present invention as shown in FIGURE 3.

Referring now to 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, FIGURES 1 and 2 illustrate the prior art to which the present invention is directed which prior art includes an apparatus A for inductively heating simultaneously the reduced portions of side-by-side workpieces B. Although it is appreciated that the workpieces may take a variety of structural shapes, the workpieces in accordance with the illustrated embodiment of the present invention include gear blanks having flanges **10** and shanks **12** which flanges have a larger transverse dimension than the shanks.

The gear blanks B are received within a guideway **14** which may be inclined so that the gear blanks slide through the guideway without rotation. Also, the guideway may be placed edgewise as well as being inclined so that the gear blanks both rotate and slide along the guideway so that the shanks **12** are uniformly heated in a manner to be hereinafter described in detail. The guideway includes spaced shoulders **16, 18** which define a guide slot **20** having a dimension which will receive the flange **10** of blanks B so that the shanks **12** extend outwardly from the guideway **14** with the shanks being substantially parallel.

The apparatus A is adapted to heat the outermost portion of shank **12** so that the end of the shank may be annealed, hardened or otherwise heat treated. To accomplish this heating operation, there is provided an inductor **30** having spaced parallel conductors **32, 34** positioned on opposite sides of the shanks **12**. The inductor **30** is characterized as having a channel **36** for allowing movement of the shanks **12** through the inductor while the shanks are in inductive relationship with the conductors **32, 34**. To power the inductor **30**, there is provided a power source **38** which, in accordance with the preferred embodiment of the present invention, is a motor generator set developing three or ten kc. alternating current. It is appreciated that the inductor **30** may have multiple turns or may be wider in an axial direction with respect to the shanks **12** so a greater portion of the shanks are in inductive relationship with the inductor. The single turn inductor **30** is shown only for representative purposes and various other inductors can be provided for simultaneously heating shanks **12** or similar reduced portions on other workpieces.

In operation of the prior art device as shown in FIGURES 1 and 2, the gear blanks B are moved through the channel **36** of inductor **30** by sliding the blanks along guideway **14**. Since the flanges **10** have a greater transverse dimension than shanks **12**, there is a considerable vacant space or volume between adjacent shanks **12**. Thus, when current flows through the conductors **32, 34** as shown in FIGURE 2, an induced voltage is developed on opposite sides of shanks **12** which induced voltage causes a heating current to flow in the portions of the shank **12** adjacent the conductors **32, 34**. Accordingly, only those portions of the shanks adjacent the conductors are directly heated and the remainder of the shank must be heated by conduction. This is inefficient and requires a considerably time delay for stabilization of the temperature within the shank **12**. If the shank **12** is to be hardened, then this localized heating may be even more troublesome because the shank must be raised to a high temperature quickly then immediately quenched. To overcome this disadvantage, the blanks B may be rotated so various portions of shank **12** are in close proximity with the conductors **32, 34**. This requires, in most instances, a more complicated arrangement for moving the gear blanks B through the channel **36**. In addition, since there is a considerable amount of vacant space in channel **36**, the heating efficiency of inductor **30** is reduced.

These disadvantages are overcome by the present invention which is illustrated in FIGURES 3 and 4 wherein inserts **40** are positioned between the shanks **12** as the gear blanks move along guideway **14**. These inserts are formed from a low resistivity, non-magnetic material such as copper. In accordance with the illustrated embodiment of the present invention, the blocks **40** are rectangular in cross section; however, they are so dimensioned to substantially fill the spaces between adjacent shanks **12** as is shown in FIGURE 4. It is appreciated that the inserts **40** could have various other configurations so that they would fill a greater portion of the space left vacant because of the difference in diameter of the shanks **12** and flanges **10**.

In some cases, the inert may be magnetic; however, this results in a loss of efficiency and somewhat offsets the advantage of the insert. With a magnetic insert, the workpiece can still be heated without drastic rotation. In addition, the insert will lose its magnetic characteristics when heated above the Curie point for the material forming the inserts.

As shown in FIGURES 3 and 4, when the gear blanks B slide along the guideway **14** past inductor **30**, the inserts **40** are positioned between the adjacent shanks **12**. The inductor is energized and current flows through conductors **32, 34** as indicated by the arrows. This flow of current in the conductors causes a corresponding current flow in the insert **40** as shown in FIGURE 4. The current flow through the inserts **40** in turn causes a corresponding current flow within the shanks **12**. Consequently, there is an even distribution of current flow around the periphery of shank **12** so that the shanks need not be rotated to a great extent as they pass longitudinally through the channel **36** of energized inductor **30**. It may be necessary to rotate the blanks B slightly to obtain complete uniformity of current distribution through the periphery of shank **12**; however, if conductor is relied upon for even distribution of heat through shanks **12**, conduction takes place quite rapidly because there are only a few areas where the current density is substantially reduced.

With the spaces between the shanks **12** filled by the low resistivity, non-magnetic inserts **40**, the efficiency of the inductor **30** is substantially higher than the efficiency of the inductor when the spaces between the shanks are vacant.

It is appreciated that the invention has been described in connection with the use of the inserts **40** between shanks **12** of gear blanks B; however, these inserts could be used between the reduced ends of axle shafts and transmission shafts as well as between the reduced ends of various other workpieces as they are progressed through a channel inductor. The present invention has been described in connection with certain structural embodiments; however, various modifications in these embodiments can be made without departing from the intended spirit and scope of the present invention as defined in the appended claims.

Having thus described my invention, I claim:

1. In an apparatus for simultaneously heating aligned reduced portions of a plurality of side-by-side workpieces including an inductor having a conductor extending along each side of the reduced aligned portions, the improvement comprising: a low resistivity, non-magnetic insert between adjacent reduced portions, said inserts substantially filling the space between said adjacent reduced portions.

2. The improvement as defined in claim 1 wherein said inserts are formed from copper.

3. An apparatus for simultaneously heating the aligned reduced portions of a plurality of side-by-side workpieces including an inductor with spaced parallel conductors, a means for supporting said workpieces with said reduced portions aligned, means for moving said aligned portions between said spaced conductors, a low resistivity insert between said workpieces and filling the spaces between said aligned reduced portions, said inserts being movable

with said workpieces, and a high frequency power source for energizing said inductor as said workpieces are passing through said conductors.

4. An apparatus as defined in claim 3 wherein said inserts are non-magnetic.

5. An apparatus as defined in claim 4 wherein said inserts are formed from copper.

6. An apparatus as defined in claim 3 wherein said supporting means is a guideway having means for allowing said workpieces to slide through said guideway with said reduced portions extending between said conductors.

7. A method for simultaneously heating the reduced portions of a plurality of workpieces comprising, aligning the workpieces in side-by-side relationship with the reduced portions aligned to produce spaces between the reduced portions of adjacent workpieces, substantially filling said spaces between the reduced portions of adjacent workpieces with inserts of low resistivity material, passing the workpieces between conductors of an inductor, and energizing said inductor with alternating high frequency current.

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