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INDUCTOR ARRANGEMENT FOR SURFACE-HARDENING FLANGED SHAFTS

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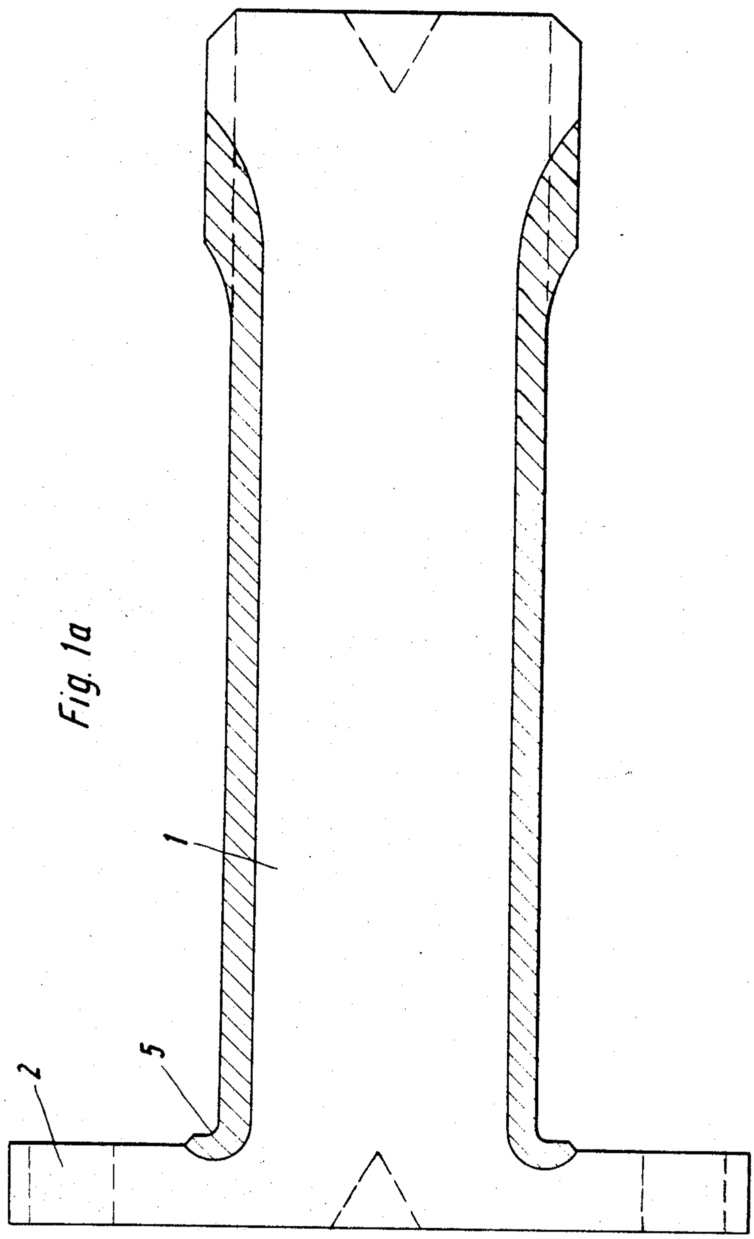

Fig. 1a

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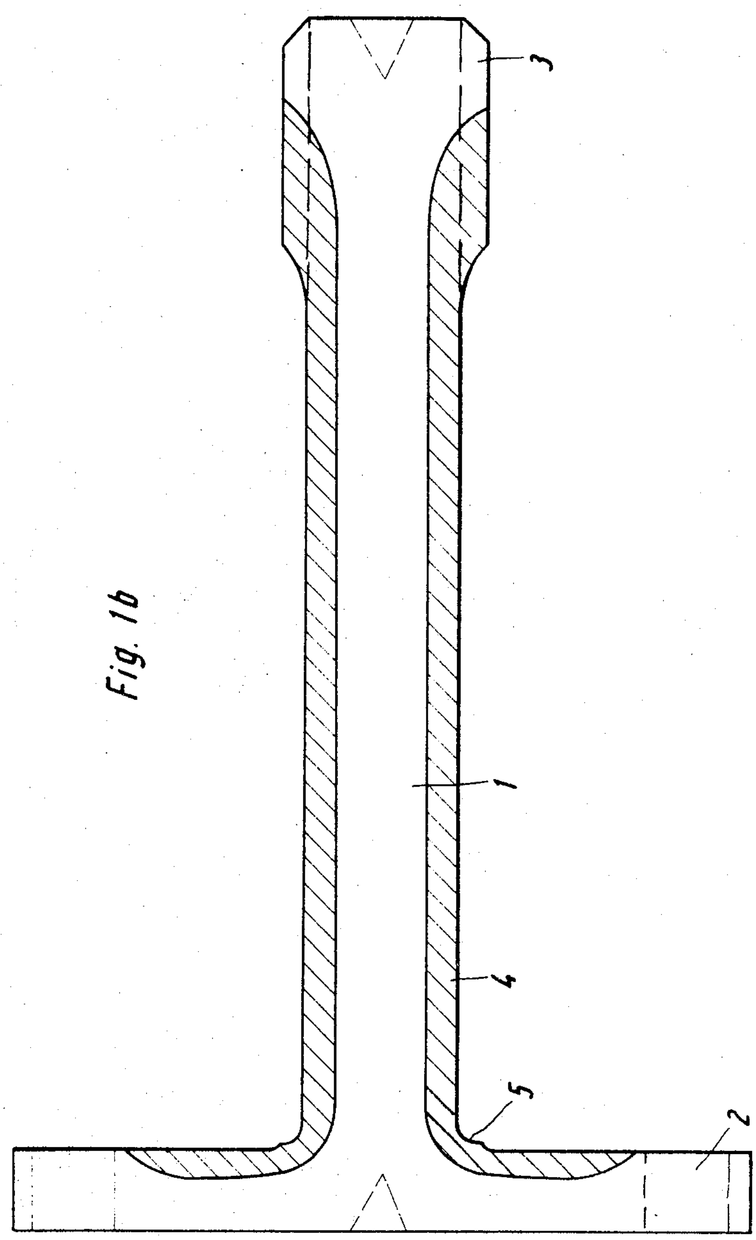

Fig. 1b

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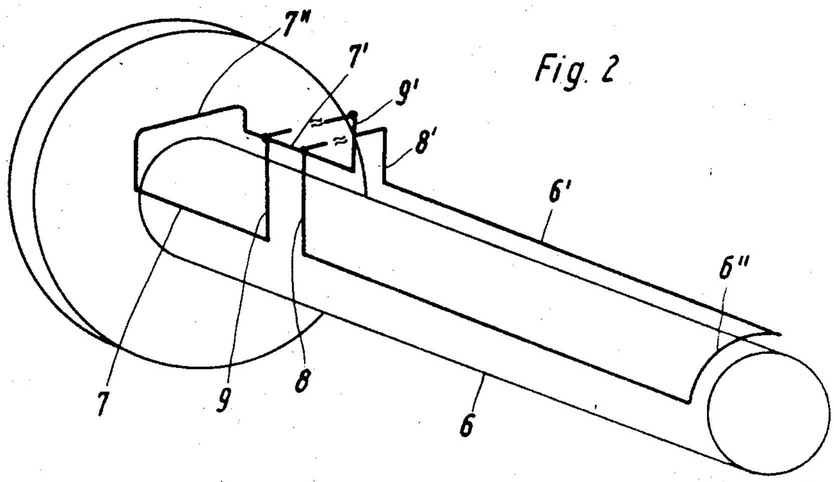

Fig. 2

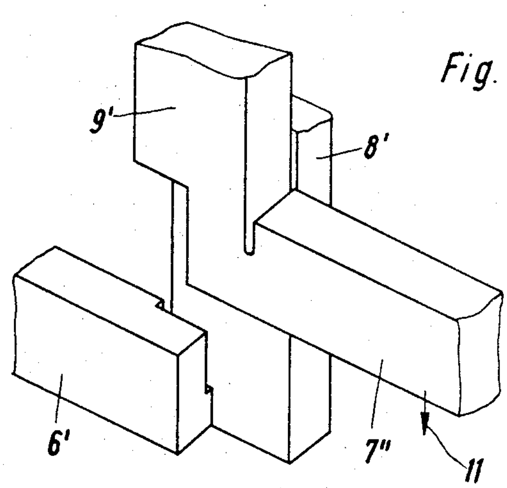

Fig. 4

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INDUCTOR ARRANGEMENT FOR SURFACE-HARDENING FLANGED SHAFTS

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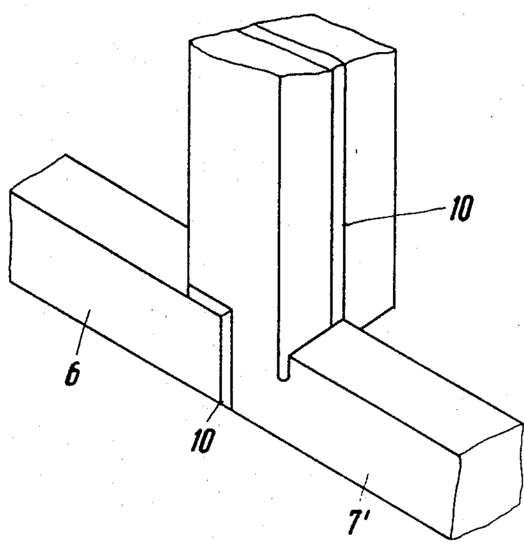

Fig. 3

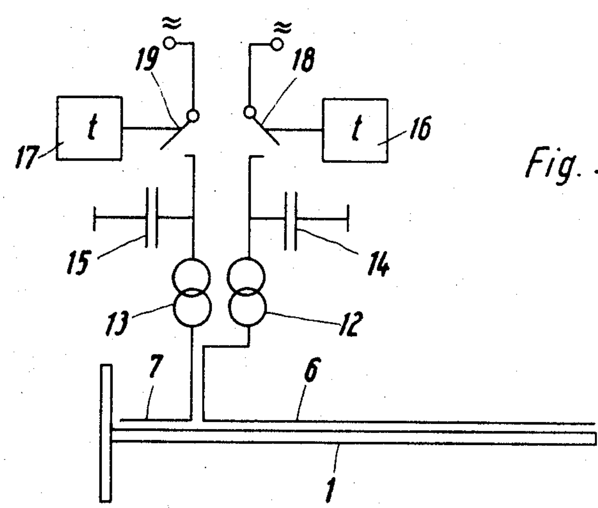

Fig. 5

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INDUCTOR ARRANGEMENT FOR SURFACE-HARDENING FLANGED SHAFTS

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U.S. Cl. 219—10.79 7 Claims

ABSTRACT OF THE DISCLOSURE

For inductively heating workpieces having a shaft portion and a flanged end, which workpieces may have different diameters of the shaft portions and/or flanges, an inductor arrangement is provided in which at least two heating conductor loops are disposed along the workpiece surface arranged so as to heat at least the entire length of the said shaft, at least one of which may be removed allowing a different one of said loops to be substituted conforming to the size of said flanged end.

This invention relates to the inductive surface hardening of workpieces having an end portion of greater diameter, for instance a plate-shaped flange. Workpieces of this configuration are used to provide for instance rear axle shafts, half shafts and propeller shafts of motor vehicles, and it is increasingly desirable if not necessary to submit practically the entire surface of such workpieces, i.e. the area comprising the surface of the shaft, highly stressed regions of the flange and the angle between shaft and flange, to inductive surface hardening.

It has previously been proposed inductively to harden such workpieces by concurrently heating the whole of their surface during rotation of the workpiece. Thus such workpieces may be hardened in this way by an inductor which extends along the entire length on one side of the workpiece whilst the latter rotates at constant speed about its axis of symmetry, the workpiece being quenched after having thus been heated.

While this method of hardening has proved reasonably satisfactory in practice, nevertheless a disadvantage is present in that for hardening a workpiece in the form of a shaft with a flange of specific dimensions, an inductor exactly conforming with the said dimensions must be specially provided to achieve the required hardening effect. This disadvantage is particularly evident when a number of workpieces are required to be thus treated, batches of the workpieces differing from each other in the diameter of the shaft and the flange. Thus apart from the capital investment cost involved in providing the large number of different inductors, the continuous changing over of inductors in the inductive hardening plant causes a considerable loss in production time.

The invention is based on the fact that for inductively surface-hardening workpieces of the type described, the manner in which the inductive treatment for achieving the required hardening of the shaft portion of the workpiece is not so critical as that which must be applied to the portion of increased diameter, e.g. a flange, and the transition angle between the shaft and the said portion of increased diameter. For example, it was found that the conductor loop of an inductor which had been designed for treating a shaft of 60 mm. diameter still gave satisfactory results on a shaft which had a 30% smaller diameter, i.e. shaft of 40 mm. diameter. Thus while it might at first sight be concluded that shaft portions of different types of flanged shafts can generally all be hardened with a single inductor, it has been discovered that there is less latitude available when it is envisaged to employ a heating conductor loop that has beeen designed for hardening a flange and flange root of a particular shape and size, for hardening flanges having dimensions differing by more than 10% from the dimensions for which the inductor was meant.

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The invention consists of an inductor arrangement for surface-hardening rotating workpieces having an elongate cylindrical shaft and an end flange of greater diameter than the shaft, comprising at least two heating conductor loops comprising a principal conductor loop for heating a portion of the said shaft, disposed parallel to the surface of the shaft in the axial direction and a secondary conductor loop for treating at least a portion of the said flange including the angle between the root of the flange and the shaft, a portion of the said secondary loop disposed parallel to the surface of the shaft in the longitudinal axial direction, and the said principal and secondary conductor loops abut each other, and wherein at least one of the said loops is replaceable.

In a preferred form of the invention, the division between the two heating conductors should be as close as possible to the root of the flange, firstly to permit the secondary conductor to be given an optimum geometrical shape and secondly to reduce the portion of the shaft heated by the secondary conductor to a minimum. When using such an arrangement for inductively heating or hardening a plurality of different types of flanged shafts, the principal heating conductor need not be exchanged; only the secondary heating conductor requiring replacement. This results not only in a considerable saving in investment cost but also in time otherwise lost in retooling the inductor.

In one embodiment of the invention conductors applying the current to the said principal and secondary heating conductor loops are juxtaposed so that one shields the other. Moreover, it is desirable axially to stagger, i.e. to axially effect adjacent, e.g. abutting ends of conductor loops.

The inductor arrangement according to the invention is capable of generating a hardened layer in workpieces which is not affected by the presence of the abutting conductor ends if the inductor is operated by a method which comprises connecting a principal conductor heating loop and a secondary conductor heating loop arranged according to the invention, for unequal lengths of time to current sources of different frequencies and different power. Preferably a current source should be used which can supply alternating current at frequencies between 500 and 500,000 c./s.

Embodiments of the invention and methods of putting the invention into effect are hereinafter described and illustrated in the accompanying drawings, of which

FIGURES 1*a* and 1*b* are longitudinal sections of two examples of flanged shafts of different dimensions, which may be hardened according to the invention,

FIGURE 2 is a schematic perspective representation of the disposition of a principal and secondary conductor heating loop arranged according to the invention,

FIGURES 3 and 4 illustrate the manner in which the heating conductors may be supplied with current at abutting ends,

FIGURE 5 is a schematic representation of a circuit arrangement for performing the method of hardening according to the invention.

Referring to FIGURES 1*a* and 1*b*, the flanged shafts of equal length illustrated thereby both have the same basic shape consisting of an elongate cylindrical shaft **1** formed at its left hand end with a plate-shaped flange **2**, the right hand end being provided with splines **3**. The two flanged shafts merely differ in the diameters of their shafts and flanges. It is desired to provide the workpiece in FIGURE 1*b* with a hardened layer 4 that differs at the flange 2 from that shown in FIGURE 1*a*. Apart from the difference in the length of the hardened zone in the flange 2 in the workpiece in FIGURE 1*b*, the hardening problem in both workpieces is identical, namely the provision of a hardened layer on the entire length of the shaft including the angle 5 at the root of the flange as well as the splines 3. However, in order to avoid the creation of zones of reduced strength, hardening must be effected from a uniform temperature, i.e. a zone conforming with the desired hardened layer must be heated uniformly and continuously throughout the surface of the workpiece.

This may be effected by using an inductor according to the invention such as that shown in FIGURE 2, which consists of a principal conductor heating loop comprising conductor portions **6** and **6′** and a secondary conductor heating loop comprising conductor portions **7** and **7′**. Cross members **6″** and **7″** and supply conductors **8, 8′** and **9, 9′** respectively complete the circuits through **6, 6′** and **7, 7′** to form heating loops extending over the workpiece surface. The two associated parallel conductor portions in each loop are separated by an angular distance not exceeding 180 degrees.

Particular attention should be paid to the design of the principal and secondary heating conductor loops at the point of abutment, so that the heated zones generated by the two conductors evenly merge. This may be achieved—as illustrated in FIGURES 3 and 4, by separating the axially abutting ends of the conductor portions **6′** and **7′** which extend parallel to the workpiece axis by an interposed insulating layer **10**, whereas the current supply conductors **8′** and **9′** are placed radially side by side in such manner that in respect of their heating effects the one shields the other. Moreover, as illustrated in FIGURE 4, the end face of each portion of heating conductor may be normal to its other faces. Nevertheless, it may sometimes be better to locate the end faces obliquely in superimposed or juxtaposed adjacence, the object being to induce currents in the workpiece in the region of high current density, i.e. at the abutments, that flow nearly exclusively in the axial direction, whereas the current supply conductor induces only a negligible amount of power.

The uniformity of the heated surface layer may be further improved by relatively staggering, lengthwise of the workpiece, the joints where the heating conductor portions **6′, 7′** and **6, 7** abut, so that the point of abutment between **6′** and **7′** may be slightly closer to the end of the workpiece than that between **6** and **7**.

It will be readily understood from FIGURE 4 that the current supply conductor **8′** associated with the principal conductor is preferably so contrived that it will incidentally locate the secondary conductor when this is inserted from above during an exchange in the direction indicated by arrow **11**.

FIGURE 5 illustrates a circuit arrangement which permits the surface heating of flanged shafts to be further improved in order to comply with practical requirements. The principal conductor **6** and the secondary conductor **7** of the inductor are connected via separate transformers **12** and **13** to a source of medium or high frequency current. Capacitors **14** and **15** in association with the transformers provide the required frequencies. The current is applied by switches **18** and **19** which are operable at different times and at different intervals under the control of timing devices **16** and **17**.

It should be noted that the proposed arrangement and the proposed method permit not only workpieces with a

plate-shaped flange, but also workpieces formed at one or both ends of the shaft with bell-shaped or convex or concave flanges, to be inductively hardened.

We claim:

1. An inductor means for surface-hardening rotating workpieces by simultaneously heating the entire length thereof, said workpieces having an elongated cylindrical member and an end flange member of greater diameter than said cylindrical member joined to said cylindrical member at an end thereof, said inductor means comprising at least a principal heating conductor loop for heating a portion of said shaft and a secondary heating conductor loop for heating said flange and the portion of said workpiece where said flange and said cylindrical member are joined, said principal loop being elongated and disposed parallel to the surface and the axis of said cylindrical member, said secondary loop being disposed parallel to the surface of said cylindrical member adjacent said flange member and said principal and secondary loops being placed in an abutting relationship, said inductor means further comprising means for supplying current to said principal and secondary loops.

2. The inductor means defined in claim **1** wherein said principal loop is permanently affixed and said secondary loop is removeable from said inductor means permitting substitution of a secondary loop conforming to the size of the flange member of the workpiece being treated.

3. The inductor means defined in claim **1** wherein said means for supplying current comprises first and second supply conductors for conducting current to said principal and secondary loops, respectively, said supply conductors being placed in a side-by-side relationship in such a manner that one of said supply conductors shields the other.

4. The inductor means defined in claim **1** where adjacent ends of said principal and secondary conductor loops are in axially offset positions.

5. The inductor means defined in claim **1** wherein said means for supplying current includes means for connecting said principal and secondary loops for unequal periods to current sources for supplying different frequencies and power to each of said loops.

6. The inductor means defined in claim **5** wherein said current sources operate at frequencies between 500 and 500,000 Hz.

7. A method of heat treating a rotating workpiece having an elongated cylindrical member with an end flange member of greater diameter being joined thereto comprising the steps of

placing a first conductor loop in a parallel relationship to the surface of said cylindrical member,

placing a second conductor loop in a parallel relationship to the surface of said cylindrical member adjacent said flange member, and

supplying for unequal periods current from sources operating at different frequencies and power to said first and second loops, respectively.

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