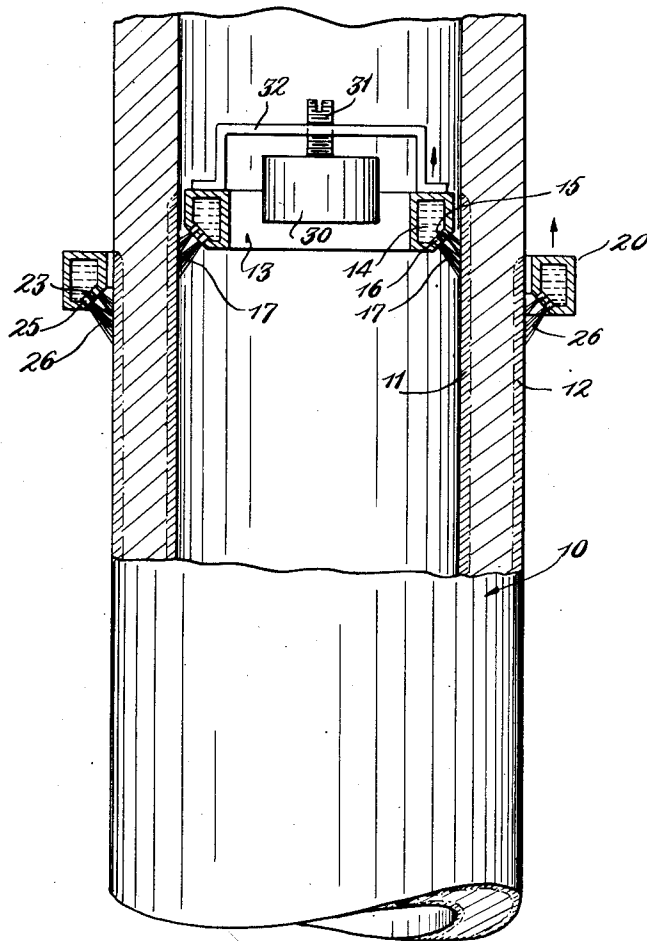


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J. T. VAUGHN
MEANS AND METHOD OF SIMULTANEOUS HARDENING OF
OPPOSITE SURFACES OF THIN METALLIC MEMBERS
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INVENTOR.
JOHN T. VAUGHAN
BY *Alfred C. Boddy*
ATTORNEY

UNITED STATES PATENT OFFICE

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MEANS AND METHOD OF SIMULTANEOUS
HARDENING OF OPPOSITE SURFACES OF
THIN METALLIC MEMBERSJohn T. Vaughan, Cleveland, Ohio, assignor to
The Ohio Crankshaft Company, Cleveland,
Ohio, a corporation of Ohio

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This invention pertains to the art of metal heat treatment and, more particularly, to method and apparatus for substantially simultaneously hardening opposite sides of a relatively-thin, quench-hardenable material leaving the portion of the material intermediate the hardened surfaces relatively unaffected by the heat-treating method.

The invention is particularly applicable to the hardening of both surfaces of track link bushings for tractors and the like using high-frequency, electric-induction heating and the invention will be described as embodied in method and apparatus for substantially simultaneously producing these two hardened layers, although it will be appreciated, of course, that the invention is not so limited.

Track link bushings are normally cylindrical in configuration and their specifications call for inner and outer hardened surfaces with an intermediate soft layer.

Heretofore, in producing such surfaces, difficulty has been met in meeting the required specifications. The wall thickness of such bushings is relatively thin. If the inner and outer surfaces are hardened in separate heat-treating operations, the heating of the last surface for hardening unduly heats the first hardened surface and effects a drawing or tempering operation thereon. The heat from the second hardening operation is conducted rapidly through the thin walls of the bushing to the already hardened surface.

Of course, the first hardened surface can be artificially cooled during the heating of the second surface but the operation is still not fully satisfactory. Two heat-treating operations are still necessary.

To eliminate the need for the two separate heat-treating operations, it has been proposed to harden the two surfaces simultaneously with the induction-heating coils disposed directly opposite each other; i. e., by heating simultaneously and subsequently quenching; for example, see the copending application of Harold A. Strickland, Jr., Serial No. 694,335 filed August 31, 1946, owned by the assignee of this application, wherein such a method and the article produced thereby is specifically described and claimed.

However, the walls of track link bushings are relatively thin and when opposite surfaces are heated simultaneously, the entire wall thickness is heated above the critical quench-hardening temperature. Subsequent quenching produces hardened metal through the entire wall thickness which does not meet the desired specifica-

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tions of a hardened inner and outer surface and a soft central core.

The present invention contemplates a method and apparatus for generally simultaneously heat treating first and second surfaces of a relatively-thin, quench-hardenable material by progressively heating both surfaces and, subsequently, quenching same, with the heat applied to the second surface being offset in the line of movement from the heat applied to the first surface and applied generally opposite the point of impingement of the quench on the first surface. Thus, the heat applied to the second surface which might drift through the material to the hardened first surface and heat the surface to a drawing or tempering temperature is rapidly removed.

If high-frequency electric heating is used for simultaneously heating both surfaces; i. e., using an internal and external inductor, balancing or controlling the power delivered to the two surfaces becomes difficult and complicated. It is desirable to connect the internal and external inductors in a permanent electrical relationship, such as parallel or series, and then to a common power source, such as an impedance matching transformer secondary. However, the tendency generally is for the external inductor to deliver greater power to the bushing, thus producing unequally hardened layers. The relative dimensions of the coils may be varied, but this usually affects the heat pattern of the coil on the workpiece.

Accordingly, the invention also contemplates apparatus for simultaneously heating opposite surfaces of a metallic article by high-frequency induction heating wherein the relative depth of heating of the two surfaces must be accurately controlled, including a high-frequency inductor disposed adjacent each surface and connected in a fixed electrical relationship, one of the inductors being provided with a magnetically permeable material adjustable relative to the inductor for varying the degree of coupling of that inductor with its adjacent surface.

In view of the above, it is an object of the present invention to provide a method and apparatus to substantially simultaneously quench harden to a controllable depth both surfaces of a relatively thin metallic article while leaving the central portion of the article in the relatively soft unhardened state, which method and apparatus avoids the objections of the prior art.

Another object of the invention is to provide a method and apparatus for substantially simultaneously quench hardening opposite surfaces of

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a relatively thin article of manufacture while leaving a relatively soft core, wherein one surface is first heated and subsequently quenched by a stream of cooling medium while the other surface is heated at a point oppositely disposed from the point of impingement of the cooling medium on the first surface and, subsequently, quenched.

Still another object is the provision of new and improved quench-hardening method and apparatus including inductors and quench means associated therewith disposed on opposite surfaces of the article being treated so relatively arranged that the quench water from one inductor coil prevents the heat from the other inductor coil heating portions intermediate the surfaces above the critical quench-hardening temperature.

Another object of the invention is the provision of improved means for balancing or adjusting the power output of two induction-heating coils connected in permanent electrical relationship to the same power source which consists of providing a magnetically permeable material for at least the coil normally tending to deliver the smaller amount of power and adjusting the size or coupling thereof to obtain the desired balance.

The invention is embodied in certain methods and steps and parts and arrangement of parts, a preferred embodiment of which will be described in this specification and illustrated in the accompanying drawing which is a part hereof, and wherein the single figure shows a sectional view of a metallic workpiece to be hardened on both sides, such as a track link bushing, with heating and quench means, such as high-frequency electrical inductors, arranged in accordance with and to carry out the methods of the present invention.

Referring now to the drawing wherein a preferred embodiment of the invention is shown only for the purposes of illustration and not for the purposes of limitation, the workpiece to be heat treated is shown as a track link bushing 10 and the means for heating the track link bushing are shown as high-frequency electric inductors 13 and 20 disposed respectively internally and externally of the bushing.

Track link bushings are normally generally thin-walled cylindrical elements, elongated and formed of a material subject to hardening by heating above the critical temperature and rapidly quenching. The bushing 10 shown has an inner surface 11 and an outer surface 12, both surfaces of which are to be hardened.

The inductor 13 as shown comprises a one-turn circular copper conductor and is coaxially positioned internally of the bushing 10 with its outer edge substantially adjacent to the inner surface 11. High-frequency electric currents circulate through this inductor from a power source not shown and induce high-frequency currents to flow circumferentially in the surface 11 to heat the surface rapidly and efficiently to above the critical or quench-hardening temperature. As the axial length of the heated area is relatively limited, the inductor is progressed axially along the length of the track link bushing, thus providing a continuous heated surface.

This heat, of course, tends to be conducted rapidly outwardly through the walls of the bushing. However, before the heat has a chance to penetrate an undue amount, it is preferred to quench the surface 11 thus producing a quench hardened surface. Quench means are thus associated with the heating means. The quench means shown are integral with the inductor 13 and are of the type generally described and

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claimed in the copending application of James B. Wadhams, Serial No. 651,243 filed March 1, 1946. As there claimed and as here shown, the inductor 13 is hollow and has an internal water passage 14. The lower outer corner of the inductor includes a downwardly and outwardly facing angular wall 15 which has a plurality of openings 16 arranged around the entire periphery thereof through which quench water 17 under pressure is ejected from the passage 14 against the heated surface 11. Thus, as the inductor is moved along the length of the bushing 10 and progressively heats the surface, the heated portion is immediately quenched by the quench water 17. The angle of the wall 15 or the angle of the holes 16 or both is so adjusted that the quench water does not climb or splash up into the inductor itself whereby the water would cool the surface before it has a chance to be entirely heated.

The inductor 20 as shown comprises a one-turn cylinder copper conductor and is coaxially positioned externally of the bushing 10 with its inner edge substantially adjacent to the outer surface 12 of the bushing. High-frequency electric currents circulated through this inductor from a power source induce high-frequency currents to flow circumferentially in the surface 12 to heat the surface rapidly and efficiently to above the critical or quench-hardening temperature.

The general construction and arrangement of the inductor 20 is substantially identical to the construction and arrangement of the inductor 13 above described. Except for the fact that the arrangement is reversed, the inductor 20 will not be further described except to say that the quench means associated therewith comprise quench openings 25 formed in a downwardly and inwardly facing wall 23 through which quench water 26 may be projected against the outer surface 12 as the inductor 20 is moved lengthwise of the bushing and leaves a heated area in passing.

In the preferred embodiment, the two inductors move upwardly simultaneously but are offset axially one from the other, the outer inductor in this instance trailing the inner inductor 13. The existence and amount of this offset forms an important part of the present invention. The outer inductor 20 is preferably disposed directly opposite or slightly below the point of impingement of the quench water 17 against the inner surface 11. Thus, the quench water 17 performs a dual function. It quenches the inner heated area progressively. At the same time, because of its rapid cooling action, it prevents the conduction of heat from the outer heated area into the central portion of the bushing wall whereby to prevent this central portion from being raised above the quench-hardening temperature. In a like manner, the quench water prevents heat from flowing from the outer heated layer into the inner hardened area and drawing or tempering it.

It will be appreciated that the inner inductor 13 could be placed opposite the quench stream 26. Also, the axial displacement of the two inductors can be varied within limits. If the inductor 20 is not spaced far enough axially from the inductor 13, through heating of the wall of the bushing will result which is undesirable. If the inductor 20 is placed too far axially behind the inductor 13, the cooling effect of the quench water 17 will be lost and the inner hardened layer will be reheated to the point where some of its hardness will be lost by drawing or tempering.

Normally, each inductor is connected to its own impedance matching transformer. Sometimes, it is desired with an operation of this type that the inner and outer inductors 13 and 20 respectively be energized simultaneously and from the same power source which is usually a one-turn secondary of an impedance matching transformer. If the two inductors are connected in a permanent electrical relationship, such as series or parallel, one inductor will normally deliver more power and thus heat its adjacent surface more than the other. Generally, this is the outer inductor if curved surfaces are involved. In order to compensate for this difference in power output to the workpiece, the inductor 13 is preferably provided with a plug 30 of magnetically permeable material such as a powdered iron core or laminations. The plug shown is adjustably supported by a threaded screw 31 on a bracket 32 fixed to the inductor 13. The size of the plug will depend on the particular installation and the size of the bushing or other articles being hardened. The size or position of the plug is varied so that the ratio of the heating on the two surfaces is equal or as desired. Magnetic laminations on high-frequency inductors are, of course, known; but, when used heretofore, the maximum number possible has been used to obtain the maximum degree of coupling. The present invention contemplates using something less than the maximum number; i. e., merely enough to obtain a desired ratio of heating with the other inductor.

Thus, in effect, there has been shown a plurality of high-frequency electrical inductors for heating individual portions of surfaces of workpieces, the inductors being connected in permanent electrical relationship, in the present embodiment in parallel, although they could be in series, to a common source, in the present embodiment the secondary of an impedance matching transformer, including means for obtaining a desired ratio of heating between the two inductors without altering the electrical connections or other electrical relationship between the inductors.

Of course, both inductors could have magnetically permeable means associated therewith, the permeability of one being greater than or less than the other, or being adjustable to such relationship.

No means have been shown in the drawing for supporting or moving the individual inductor coils relative to the workpiece. Such means are considered relatively conventional. Likewise, the bushing can remain stationary and the inductor move or vice versa, or a combination of movement of each may be utilized.

In heating track link bushings, it may be necessary to protect the ends of the bushing from overheating because of concentration of flux thereat. This may be done by providing a magnetic flux extender for the ends of the bushing as described and claimed in the patent to Somes, Reissue No. 22,064 or No. 2,209,303, or the power supplied to the inductors may be varied as taught in the patent to Denneen and Dunn, No. 2,202,759.

It will be appreciated that the invention can be used on other articles such as flat plates or the like. As the article becomes thicker, however, the need for the invention decreases as the wall has sufficient thickness to prevent through heating even though the inductors are oppositely disposed. It is preferred that the frequency of the electrical power be high enough that the actual

heating currents induced in the workpiece remain quite close to the surface so as to minimize to a maximum the tendency to heat the intermediate portion of the walls of the bushing.

It will be appreciated that modifications will occur to others upon a reading and understanding of this specification. It is my intention to cover all such modifications insofar as they come within the scope of the appended claims.

Having thus described my invention, I claim:

1. A method of substantially simultaneously heat treating first and second cylinder surfaces on a cylindrical member formed of a quench-hardenable material, leaving the central portion between the surfaces in a relatively soft state, comprising, in combination, the steps of progressively heating said first surface above the critical temperature, subsequently and progressively directing a quenching medium onto said heated surface, progressively heating said second surface generally opposite the point where said quenching medium strikes said first surface and, subsequently, quenching said second surface.

2. A method of heat treating a first and second surface on a metallic member formed of a quench-hardenable material, comprising, in combination, the steps of progressively heating said first surface, directing a quenching medium against said first surface, progressively heating said second surface generally opposite the point of impingement of said quenching medium against said first surface and progressively quenching said heated second surface.

3. Apparatus for simultaneously progressively hardening first and second opposite surfaces on a relatively thin member formed of a quench-hardenable material, comprising, in combination, a high-frequency electric inductor adapted to be positioned adjacent said first surface, quench means associated with said inductor and adapted to quench the surface heated by said inductor, a second inductor adapted to be positioned adjacent said second surface, quench means associated with said second inductor to quench the surface heated by said second mentioned inductor, said second inductor being offset from said first inductor to be generally opposite the point of impingement of the quenching medium of said first mentioned quenching means on said first surface and means for moving both of said inductors relative to said surface.

4. Induction-heating apparatus for heating substantially simultaneously both surfaces of a generally cylindrical member, said apparatus comprising, in combination, a pair of coaxially arranged high-frequency electric inductors connected to a common power source in a fixed electrical relationship, one adapted to be disposed exteriorly of said member, the other adapted to be disposed interiorly of said member and having an inherently poor electrical coupling factor with its opposite surface than the inductor disposed exteriorly of said member, said interior inductors having magnetically permeable material associated therewith to increase the heating effect thereof to balance with said exterior inductor.

5. The combination of claim 4 wherein adjusting means are provided for moving said magnetically permeable material relative to said inductor.

6. The method of adjusting the ratio of heating of a pair of high-frequency electrical inductors adapted to heat generally simultaneously inner and outer surfaces of a cylindrical member comprising disposing said inductors in generally

coaxial relationship, one interiorly of and the other exteriorly of said member, connecting said inductors in a fixed electrical relationship to a power source, providing one of said inductors with magnetically permeable material and adjusting said material relative to said inductor in an amount and degree of coupling to provide the desired ratio of heating.

7. Induction-heating apparatus for simultaneously quench hardening first and second opposite surfaces of a relatively thin member formed of a quench-hardenable material comprising first and second high-frequency electric inductors adapted to be disposed in inductive heating relationship with said first and second surfaces respectively, means for moving said inductors relative to said surfaces as a unit, quench means associated with said first inductor and adapted to quench the surface heated thereby, said second inductor being positioned adjacent said second surface generally opposite the point of impingement of the quenching medium of said quench means on said first surface, said inductors being electrically connected together in unadjustable relationship, one of said inductors having magnetically permeable material associated therewith in an amount to provide a desired ratio of heating between said inductors.

8. The method of hardening the first and second opposite surfaces of the wall of a thin cylindrical member formed of a high-carbon, quench-hardenable steel which comprises: progressively in an axial direction inducing alternating currents to flow in an axially-narrow, circular direction in one of said surfaces for such a limited

length of time and of such a high-frequency and power density that only a surface layer of said surface is heated above the quench-hardening temperature for the particular steel employed; then immediately and vigorously quenching said surface while simultaneously and generally opposite the point of impingement of said quench progressively in an axial direction inducing alternating currents to flow in an axially-narrow, circular direction in said second surface for such a limited length of time and of such a high-frequency and power density that only a surface layer of said second surface is heated above the quench-hardening temperature of the particular steel employed and the portion below the layer including said first surface remains below said temperature, but which portion would otherwise normally rise to a drawing temperature for the hardened layer on said first surface, except for the quench on said first surface maintaining said first surface in a cooled state; and then immediately quenching said second surface.

JOHN T. VAUGHAN.

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