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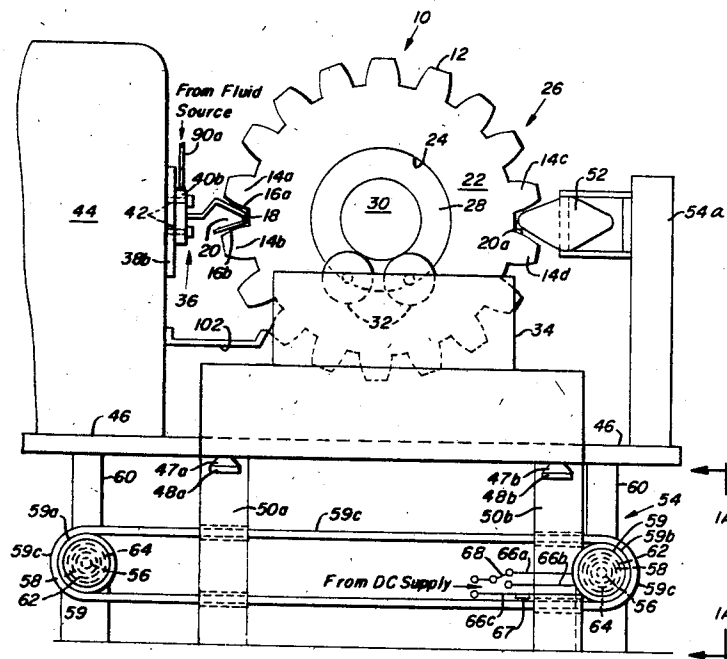
[54] **APPARATUS FOR CASEHARDENING A TOOTHED
 ARCUATE MEMBER**
 12 Claims, 6 Drawing Figs.

[52] U.S. Cl. 266/4,
 148/147, 219/10.59, 219/10.71
 [51] Int. Cl. C21d 1/10,
 C21d 1/66
 [50] Field of Search 266/4 E, 5,
 6, 8, 4; 219/10.59, 10.71

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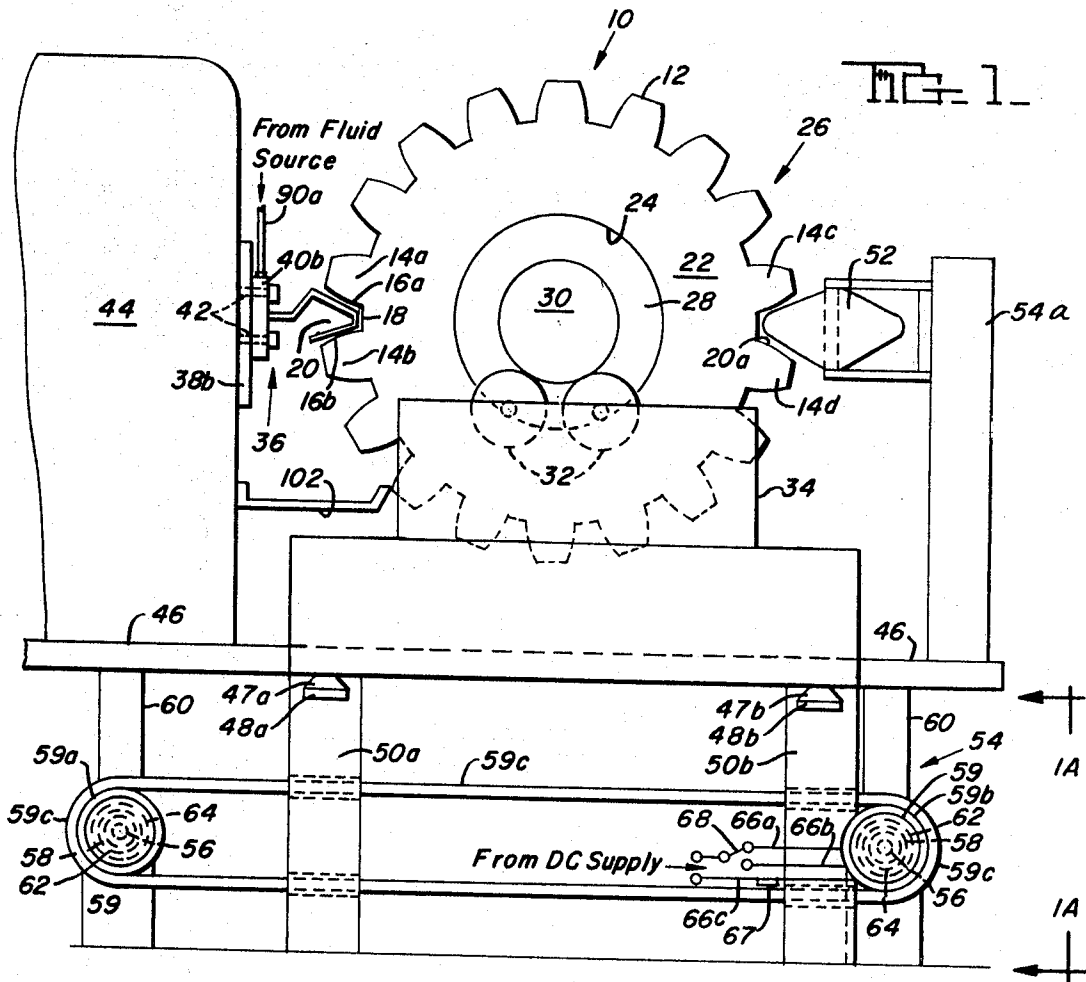
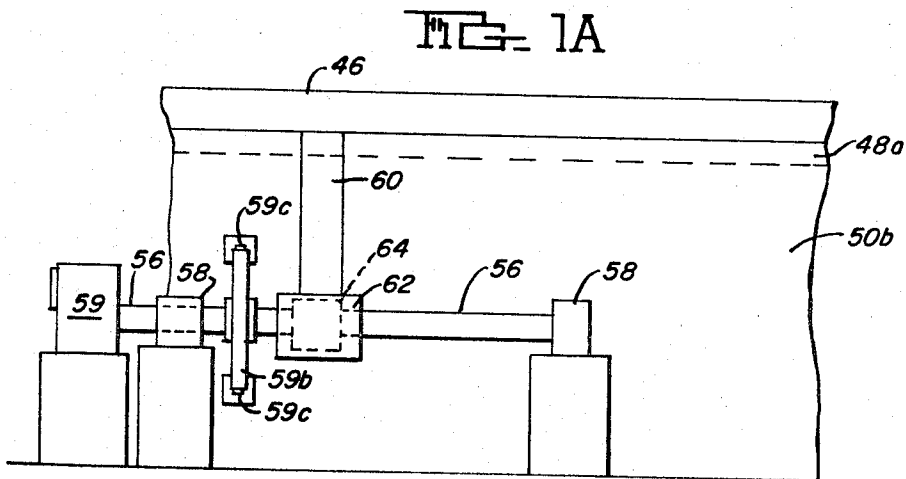
ABSTRACT: This disclosure relates to the surface hardening of arcuate members and, more particularly, to an improved apparatus for and method of surface hardening an arcuate member, such as a large pitch gear, having a first tooth and a second tooth, each tooth having opposed flanks and a root section which define a valley. The apparatus has supporting means for supporting the arcuate member, casehardening means mounted in registry with the valley for casehardening the flanks and the root section, and drive means connected to one of the supporting means and the casehardening means to cause relative movement between the valley and the casehardening means so that the casehardening means passes through the valley. The casehardening means has preheating means generally contoured to the valley for producing a moving preheated area on the flanks and the root section, heating means adjacent the preheating means for raising the temperature of the arcuate member without burning the moving heated area, and quenching means connected to a fluid source and adjacent the heating means for quenching and casehardening the moving heated area.



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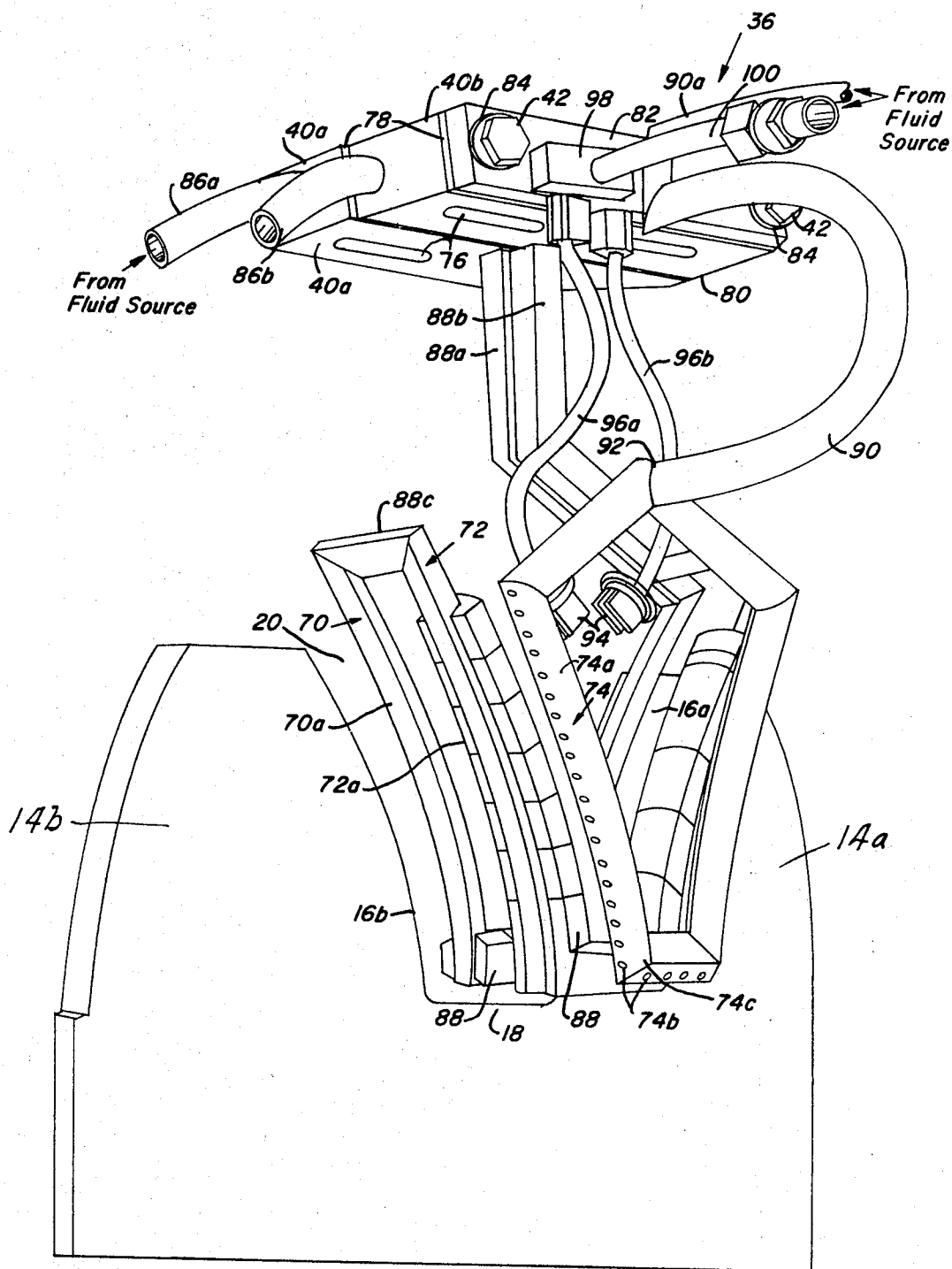
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SHEET 1 OF 3



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FIG. 2.



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FIG. 3

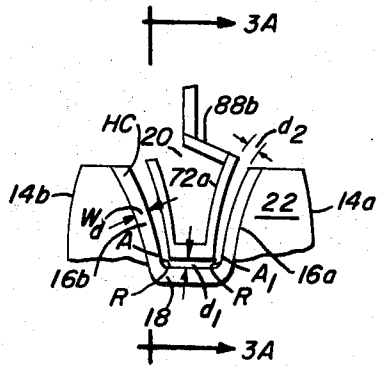


FIG. 3A

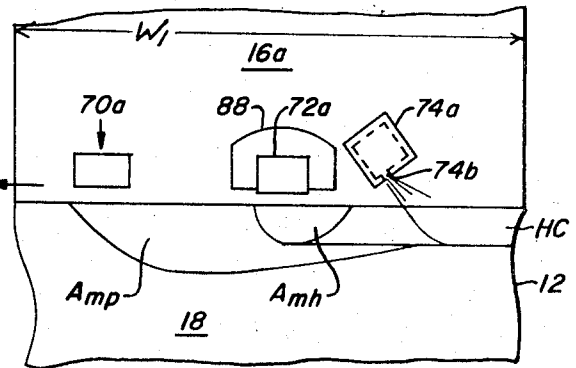
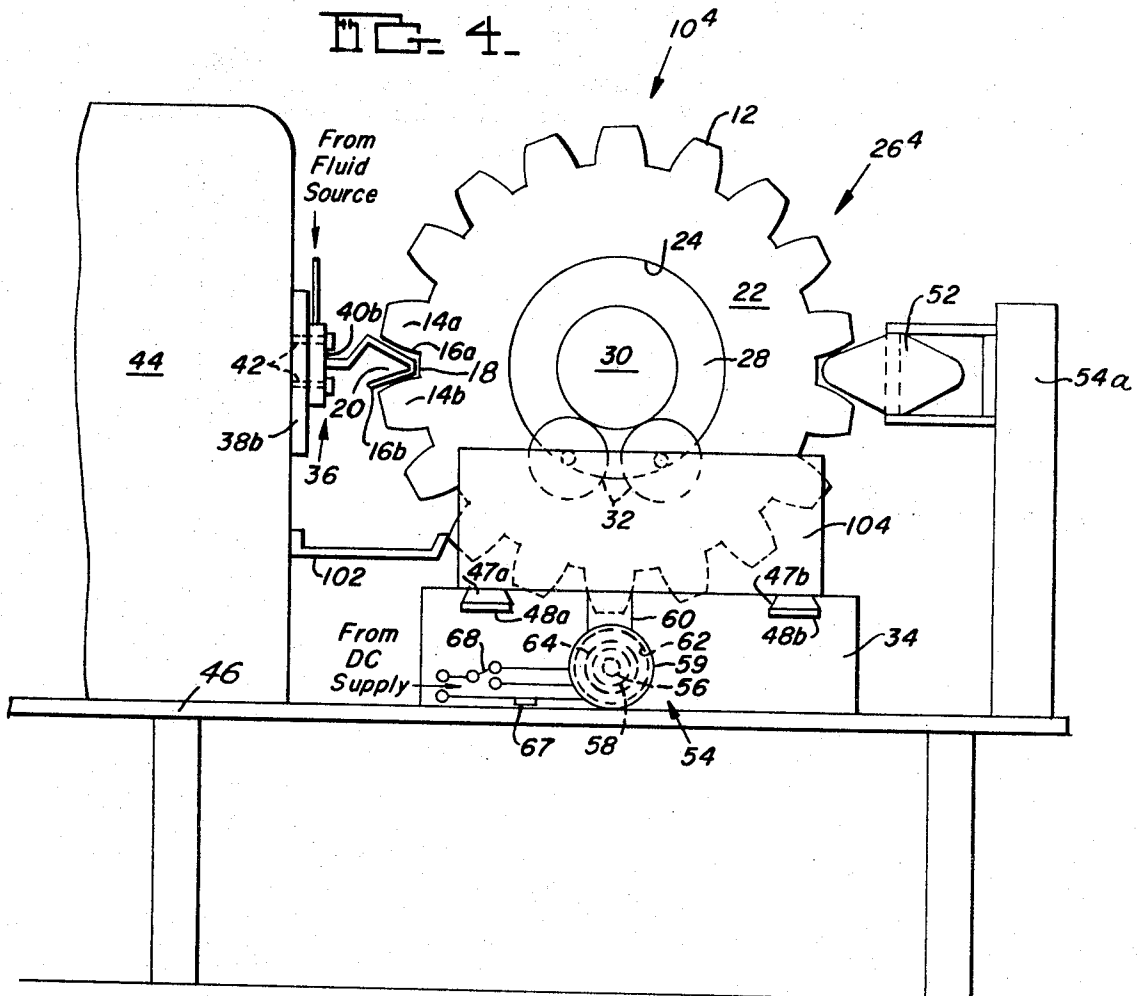


FIG. 4



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APPARATUS FOR CASEHARDENING A TOOTHED ARCuate MEMBER

BACKGROUND OF THE INVENTION

Heretofore, an arcuate member, such as a large pitch gear, having a first tooth and a second tooth provided with opposed flanks and a root section which defined a valley was hardened by heating the entire gear in a conventional furnace followed by quenching in a suitable quench. The member is then softened by tempering to achieve necessary toughness, which resulted in a surface much less wear-resistant than if the member had been casehardened. Large pitch gears are in the range of 0.500—0.625 diametral pitch where diametral pitch is number of teeth/pitch diameter. Such large pitch gears are not commonly casehardened because of the deep cases required and because modern applications require that the case follow the complete contour of the valley formed by two teeth. Contour hardening is needed to impart compressive prestress at the valley radii increasing the fatigue strength at this critical area. The conventional method to contour caseharden by induction would require a much greater power source than is normally employed and would likely burn the surface in achieving the deep cases required. Another known induction technique, the tooth enveloping coil, cannot harden the root of the valley and cannot control the contour of the case.

OBJECTS OF THE INVENTION

It is the general object of the present invention to avoid and overcome the foregoing and other difficulties of and objections to prior art practices by the provision of an improved apparatus for and method of casehardening an arcuate member, such as a large pitch gear, having a first tooth and a second tooth provided with opposed flanks and a root section which define a valley, which method and apparatus:

1. require a minimal power requirement to caseharden the arcuate member;
2. provide uniform control of the depth of and the location of the hardened case on the flanks and root section of the arcuate member;
3. are adapted to caseharden arcuate members of any diameter;
4. provide a tough ductile core in the arcuate member, which core is not affected by the casehardening process and is not undesirably hardened or embrittled;
5. caseharden the arcuate member economically without burning or melting the flanks and root section of such arcuate member; and
6. impart a compressive prestress at the radii of the root section, thereby increasing the fatigue strength of the arcuate member.

BRIEF SUMMARY OF THE INVENTION

The aforesaid objects of this invention and other objects which will become apparent as the description proceeds are achieved by providing an improved apparatus for surface or casehardening an arcuate member, such as a large pitch gear, having a first tooth and a second tooth provided with opposed flanks and an adjacent root section which define a valley. The apparatus has supporting means for supporting the arcuate member, casehardening means mounted in registry with the valley for casehardening the flanks and the root section, drive means connected to one of the supporting means and the casehardening means to cause relative movement between the valley and the casehardening means so that the casehardening means passes through the valley. The casehardening means has preheating means generally contoured to the valley to pre-heat a moving heated area on the flanks and the root section, heating means adjacent the preheating means and also generally contoured to the valley for raising the temperature of the moving heated area above the hardening temperature of

the arcuate member without burning or melting the moving heated area, and quenching means adjacent the heating means and connected to a fluid source and for quenching and casehardening the moving heated area to a predetermined uniform depth.

The improved method of surface or casehardening includes the steps of:

1. supporting the arcuate member;
2. preheating a moving heated area on the flanks and the root section;
3. heating the moving heated area above the hardening temperature of the arcuate member without burning the arcuate member; and
4. quenching the moving heated area to caseharden such moving heated area to a predetermined uniform depth.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a diagrammatic side elevational view of the apparatus for surface hardening the arcuate member, such as the large pitch gear, and including the supporting means, the casehardening means and the drive means;

FIG. 1A is a fragmentary side elevational view taken along the line IA-IA of FIG. 1 in the direction of the arrows and showing the details of the drive means;

FIG. 2 is a perspective view of two adjacent teeth on the arcuate member or gear and showing the preheating means, the heating means and the quenching means about to enter the valley defined by the opposed flanks and root section of the two adjacent teeth preparatory for the casehardening of such flanks and root section;

FIG. 3 is a fragmentary side elevational view of two adjacent teeth on the gear and showing the tapered spacing of, for example, the preheating means from the opposed flanks of such teeth and the spacing of the preheating means from the adjacent root section and the uniform casehardening thereof;

FIG. 3A is a schematic fragmentary vertical sectional view taken along the line IIIA-III A of FIG. 3 and showing the moving preheated area, the moving heated area and the hardened case; and

FIG. 4 is a fragmentary view similar to FIG. 1 wherein the supporting means is reciprocable on the frame of the surface-hardening apparatus by the drive means.

Although the principles of this invention are broadly applicable to the casehardening of arcuate members, this invention is particularly adapted for use in conjunction with the controlled, low-power induction heating of arcuate members, such as large pitch gears, to caseharden them and hence it has been so illustrated and will be so described.

DETAILED DESCRIPTION

With specific reference to the form of this invention illustrated in the drawings, and referring particularly to FIG. 1, a surface-hardening apparatus is indicated generally by the reference numeral 10.

This surface-hardening apparatus 10 is employed to caseharden an arcuate member, such as a large pitch gear 12 (FIG. 1), having a first tooth 14a (FIGS. 1, 2, 3) and a second tooth 14b, each provided with opposed flanks 16a and 16b respectively and a root section 18 (FIGS. 1, 2, 3, 3A) which define a valley 20. As shown in FIG. 3 the root section 18 extends along the bottom of the valley 20 from A to A₁ and has a root radius R. This gear 12 has a core 22 (FIGS. 1, 3) and is provided with a central mounting hole 24 (FIG. 1).

SUPPORTING MEANS 26

The apparatus 10 has a supporting means 26 (FIG. 1) for supporting the gear 12. In order to mount and support the gear 12, the supporting apparatus 26 has plates 28 (FIG. 1) mounted in the mounting hole 24 and on a shaft 30, which shaft 30 is supported on rolls 32 journaled in a stationary portion of the frame 34 of the apparatus 10.

CASEHARDENING MEANS 36 IN GENERAL

Referring to the left-hand portion of FIG. 1, casehardening means 36 are mounted in registry with the valley 20 for casehardening the flanks 16a and 16b and the root section 18 of the valley 20. The structure utilized to mount the casehardening means comprises bus bars (with only bus bar 38b being shown in FIG. 1) to which fluid-cooled half blocks 40a and 40b (FIGS. 1, 2) of the casehardening means 36 are secured by bolts 42. The bus bars including bus bar 38b are in turn connected to an electric power source, suitably a transformer 44 (FIG. 1). In order to permit relative movement between the transformer 44 and the casehardening means 36 and the gear 12 and the frame 34, the transformer 44 is mounted on a table 46 (FIGS. 1, 1A), which table 46 has slides 47a, 47b (FIG. 1) reciprocable respectively in guides a,a and 48b mounted on side rails 50a, 50b (FIG. 1) respectively of the frame 34. For the purpose of maintaining the casehardening means 36 in registry with the valley 20, a guide roll 52 (FIG. 1) projects from a bracket 54a upstanding from the table 46 and engages a valley 20a between two other teeth 14c, 14d of the gear 12 (in this case substantially diametrically offset from the teeth 14a, 14b which define the valley 20).

DRIVE MEANS 54

Drive means 54 (FIGS. 1, 1A) are connected to one of the supporting means 26 and the casehardening means 36 (in this case the casehardening means 36) to cause relative movement between the valley 20 and the casehardening means 36 so that the casehardening means 36 passes through the valley 20 (FIG. 2). The drive means 54 has a pair of screws 56 (FIGS. 1, 1A) journaled in end bearings 58 (FIG. 1A) and one of the screws 56 (in this case the right-hand screw 56) is driven by a reversible DC motor 59 (FIG. 1A) mounted on such right-hand screw 56 and supported by the adjacent end bearing 58 (FIG. 1A). The left-hand screw 56 is connected to the right-hand screw 56 and driven thereby by sprockets 59a, 59b (FIG. 1) and a chain 59c (FIGS. 1, 1A). In turn a pair of depending brackets 60 (FIGS. 1, 1A) depend from the table 46 and terminate in collars 62, which collars 62 have journaled therein a screw collar 64 which rides on the adjacent screw 56. Referring to the lower right-hand portion of FIG. 1, the motor 59 is connected to a suitable DC supply indicated by the legend "DC SUPPLY" by three leads 66a, 66b and 66c (FIG. 1). For the purpose of reversing the motor 59, a reversing switch 68 (FIG. 1) alternately connects the leads 66a and 66b to one side of such DC supply. The means utilized to control the speed of the motor 59 is a control member, such as the variable resistor 67 (FIG. 1).

SPECIFIC DETAILS OF THE CASEHARDENING MEANS 36

The casehardening means 36 has a preheating means 70 generally contoured (FIG. 2) to the valley 20 to preheat a moving area A_{mp} (FIG. 3A) on the flanks 16a, 16b and the root section 18. In addition, heating means 72 (FIG. 2), also generally contoured to the valley 20, is disposed adjacent the preheating means 70 to raise the temperature of the moving preheated area A_{mp} above the hardening temperature forming the deeply heated area A_{mh} (FIG. 3A). In addition, quenching means 74 (FIG. 2) are connected by pipes 90, 90a to a fluid source (indicated by the legend "FROM FLUID SOURCE," FIG. 2) and are disposed adjacent the heating means 72 for quenching and casehardening the moving heated area A_{mh} . The preheated area A_{mp} (FIG. 3A) preceding the hardening heat enables deeper penetration of the heated area A_{mh} without burning or melting of the surface.

As shown in FIG. 2, the two hollow half-blocks 40a, 40b are each provided with elongated mounting slots 76 to facilitate the mounting of such half-blocks 40a, 40b by means of the bolts 42 on the bus bars 38a, 38b respectively. In order to electrically insulate the two half-blocks 40a, 40b from each other and to integrate the blocks 40a, 40b, an insulating spacer 78

formed of a dielectric material, such as Bakelite or the like, is disposed therebetween and the half-blocks 40a, 40b are mounted on an insulating block 80, suitably Bakelite or the like, by bolts 42 (not shown in the right-hand portion of FIG. 2) extending through the insulating block 80 and threadable into the half-blocks 40a, 40b. A side mounting plate 82 (FIG. 2) is mounted on the half-block 40b and is insulated and spaced from such half-block 40b and the bolts 42 by an insulating spacer 78, insulating washers 84 and an insulating sleeve (not shown) disposed about the bolts 42. Bakelite is the trade name of a dielectric material manufactured by Union Carbide Corporation, New York, N.Y.

For the purpose of carrying cooling water to the preheating means 70 and heating means 72, conduits 86a, 86b (FIG. 2) extend from a suitable fluid source indicated by the legend "FROM FLUID SOURCE" into the half-blocks 40a, 40b respectively and adjacent conduits 88a, 88b depend from the respective half-blocks 40a and 40b downwardly therefrom. The left-hand conduit 88a (FIG. 2) extends to the preheating means 70, suitably an induction preheating coil 70a formed of, for example, copper tubing, which induction preheating coil 70a is connected by a bridge conduit 88c to the heating means 72, suitably an induction heating coil 72a, in series with the preheating induction coil 70a. The other end of the induction heating coil 72a is connected to the other conduit 88b (FIGS. 2, 3).

In order to minimize the width of the moving heated area A_{mh} (FIG. 3A) and concentrate the heating effect of heating coil 72a (FIGS. 2, 3, 3A) on the flanks 16a, 16b, and the root section 18, intensifying means, such as the intensifiers 88 (FIG. 2), are mounted on the portions of the heating induction coil 72a which move adjacent such flanks 16a, 16b and the root section 18. In order to obtain balanced preheating of the difficult to heat root section 18, similar intensifiers 88 are mounted on the bottom portion of the preheating induction coil 70a adjacent the root section 18. These intensifiers 88 are formed of ferromagnetic plastic, for example, powdered iron, dispersed in a plastic binder as disclosed in U.S. Pat. No. 2,777,041, issued Jan. 8, 1957 to H. C. Dustman, or of the type known as FERROTRON and manufactured by the Polymer Corporation, Reading, Pa.

The quenching means 74 is suitably a quenching head 74a (FIGS. 2, 3A) formed of hollow copper tubing, for example, which tubing has a generally diamond-shaped horizontal cross section and is provided with a plurality of quenching holes 74b (FIGS. 2, 3) on the rearward face 74c (as viewed in FIG. 2) of the quenching head 74a to prevent adverse premature cooling of the already-heated portion A_{mh} (FIG. 3A) of the valley 20. The quenching head 74a is joined to the fluid supply conduit 90 at 92, which supply conduit 90 is affixed to the side mounting plate 82 and continues via pipe 90a to the fluid source indicated in the upper right-hand portion of FIG. 2 by the legend "FROM FLUID SOURCE." The fluid employed in the preheating induction coil 70a, and the heating induction coil 72a is water. The fluid employed in the quenching head 74a may, for example, be water, oil, or a mixture of water and Aqua Quench, a water-soluble resinous material used as a water additive for water-quenching systems to provide a quenching rate between that of water and the fastest quenching oil. Aqua Quench is manufactured by the E. F. Houghton and Company, Philadelphia, Pa.

For the purpose of cooling the intensifiers 88 on the heating induction coil 72a and on the preheating induction coil 70a, spray heads 94 (FIG. 2) are directed at such intensifiers 88 and are connected by lines 96a, 96b to a manifold block 98 on the side mounting plate 82. The manifold block 98 is connected by the supply line 100 to the fluid source indicated in FIG. 2 by the legend "FROM FLUID SOURCE." The supply fluid material in this case is water. The intensifiers 88 are cooled below a temperature in the range of about 450°—500° F., their breakdown temperature by a fine atomized mist from the spray heads 94. The fluid from the quenching head 74a and the spray heads 94 are collected in a tray 102 (FIGS. 1, 4) mounted on the transformer 44.

EXAMPLES

If the gear 12 is composed of a type 1050 steel having about 0.50 percent by weight carbon and 0.91 percent manganese, the preheating coil 70a must raise the temperature of the moving preheated area A_{mp} (FIG. 3A) above the temperature of about 500° to 600° F. and the heating coil 72a must raise such moving heated area A_{mh} above a hardening temperature of about 1,650° F. to austenitize the gear 12 without burning or melting such gear 12. Prompt cooling by the quenching head 74a below about 200° F. will provide a proper martensitic content with a Rockwell hardness of about 60.

When a gear 12 is formed, for example, of a modified type 4150 alloy steel having by weight a carbon steel content of about 0.55 percent, a manganese content of about 0.60 percent, a chromium content of about 1.03 percent, a molybdenum content of about 0.19 percent and a nickel content of about 0.36 percent, the preheating coil 70a and the heating coil 72a raise the moving heated areas A_{mp} and A_{mh} (FIG. 3A) above the temperature of about 450°—500° F. and about 1,550° F. respectively and upon self-quenching through the mass of the gear 12 below 450° F., a Rockwell hardness of about 55 is produced.

Gears 12 having a diametral pitch in the range of about 0.500—0.625 were casehardened to uniform case depths W_d (FIG. 3) of about one-fourth to three-eighths inch using 100 kw., 10,000 cycle power with the spacing d_1 of the coils 70a, 72a from the root section 18 (FIG. 3) equal to about one-third the spacing d_2 of such coils 70a, 72a from the top of the flanks 16a, 16b. Along the flanks 16a, 16b the spacing increased upwardly gradually from d_1 to d_2 . Closer proximity is employed at the root section 18 to balance the heating of the more difficult to heat root section 18 with the more easily heated flanks 16a, 16b. The coils 70a, 72b and quenching head 74a move through the valley 20 having a width W_1 (FIG. 3A) of about 3 inches at a speed of about 6 inches per minute.

ALTERNATIVE EMBODIMENTS

It will be understood by those skilled in the art that alternatively, as shown in FIG. 4, the supporting means 26' has a carriage 104 having slides 47a, 47b which are reciprocable in guides 48a, 48b provided in the frame 34 and the drive means 54' is connected to the carriage 104.

METHOD

It will be understood from the above description of the improved apparatus 10, 10' shown in FIGS. 1, 4, that an improved method is also provided for surface-hardening an arcuate member, such as a large pitch gear 12, having a first tooth 14a and a second tooth 14b provided with opposed flanks 16a, 16b respectively and a root section 18 which define a valley 20. This method includes the steps of supporting the arcuate member or gear 12, preheating a moving preheated area A_{mp} (FIG. 3A) on the flanks 16a, 16b and the root section 18, heating the moving heated area A_{mh} above the hardening temperature of the arcuate member or gear 12 without burning or melting such gear 12, and quenching the moving heated area A_{mh} to caseharden such moving heated area A_{mh} .

SUMMARY OF THE ACHIEVEMENT OF THE OBJECTS OF THE INVENTION

It will be recognized by those skilled in the art that the objects of this invention have been achieved by providing an improved apparatus 10 (FIG. 1) and 10' (FIG. 4) for an improved method of casehardening the arcuate member or gear 12, which apparatus 10, 10' and method require minimal power to caseharden the arcuate member 12, provide uniform control of the depth W_d (FIG. 3) and the location of the hardened case HC (FIGS. 3, 3A) on the gear 12, are adapted to caseharden gears 12 of any diameter, provide a tough ductile core 22 (FIG. 3) in the gear 12, which core 22 is unaffected by the casehardening process and is not undesirably hardened or embrittled, which satisfactorily and economically

caseharden the gear 12 without burning or melting it, and impart a compressive prestress at the radii R (FIG. 3) of the root section 18, thereby measurably increasing the fatigue strength of the gear teeth 14a, etc.

While in accordance with the patent statutes preferred and alternative embodiments of this invention have been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby.

I claim:

1. Apparatus for surface-hardening an arcuate member having a first tooth and a second tooth, each tooth having opposed flanks and a root section which define a valley, said apparatus having:

- a. supporting means for supporting said arcuate member and having positioning means for fixedly locating said valley;
- b. casehardening means mounted in registry with said valley for casehardening said flanks and said root section;
- c. drive means connected to one of said supporting means and said casehardening means to cause relative movement between said valley and said casehardening means so that said casehardening means passes through said valley;

1. said casehardening means having:

- a. preheating means generally contoured to said valley to preheat a moving preheat area on said flanks and said root section;
- b. heating means adjacent said preheating means and generally contoured to said valley to then raise the temperature of a portion of said moving preheated area above the hardening temperature of said arcuate member without burning said portion of said moving preheat area to form a heat hardened portion, said heating means defining with said root section a spacing d_1 and with the top of said opposed flanks a spacing of d_2 , said spacing d_1 having about one-third of said spacing d_2 to balance the heating of said root section with the heating of said flanks; and
- c. quenching means adjacent said heating means, generally contoured to said valley and connected to a fluid source for quenching and casehardening another portion of heat hardened portion to form a casehardened portion and
- d. said preheating means, said heating means and said quenching means being sequentially moved relative to said valley.

2. The apparatus recited in claim 1 wherein said heating means has intensifier means to minimize the width of said movable heated area.

3. The apparatus recited in claim 1 wherein said preheating means is an induction coil connected to a power source.

4. The apparatus recited in claim 1 wherein said heating means is an induction coil connected to a power source.

5. The apparatus recited in claim 1 wherein said preheating means and heating means are in series.

6. The apparatus recited in claim 1 and having intensifier means of ferromagnetic material.

7. The apparatus recited in claim 1 wherein said one is said casehardening means.

8. The apparatus recited in claim 1 wherein said one is said supporting means.

9. The apparatus recited in claim 1 wherein said preheating means defines with said root section a spacing d_1 and with the top of said opposed flanks a spacing of d_2 , said spacing d_1 being about one-third of said spacing d_2 to balance the preheating of said root section with the heating of said flanks.

10. The apparatus recited in claim 9 wherein the spacing between said preheating means and said flanks gradually tapers from said spacing d_1 to said spacing d_2 .

11. The apparatus recited in claim 1 wherein the spacing between said heating means and said flanks gradually tapers from said spacing d_1 to said spacing d_2 .

12. The apparatus recited in claim 2 and having a spray head for cooling said intensifier means.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,593,973 Dated July 20, 1971

Inventor(s) Edward H. Dehn

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet insert -- [73] Assignee United States Steel Corporation --.

Column 3, line 16, "a,a" should read -- 48a --.

Signed and sealed this 2nd day of May 1972.

(SEAL)

Attest;

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents