Oct. 6, 1970 E. H. DEHN 3,532,333

APPARATUS FOR AND METHOD OF CASE-HARDENING AN ARCUATE MEMBER

Filed Dec. 21, 1967 3 Sheets-Sheet 1

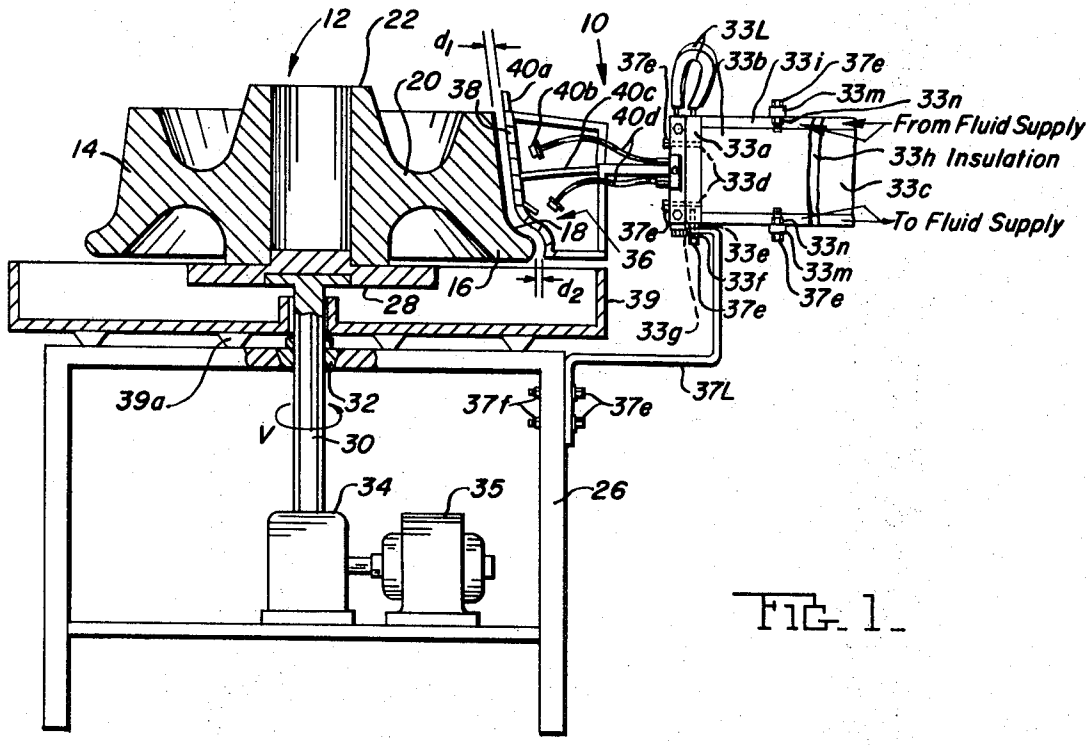
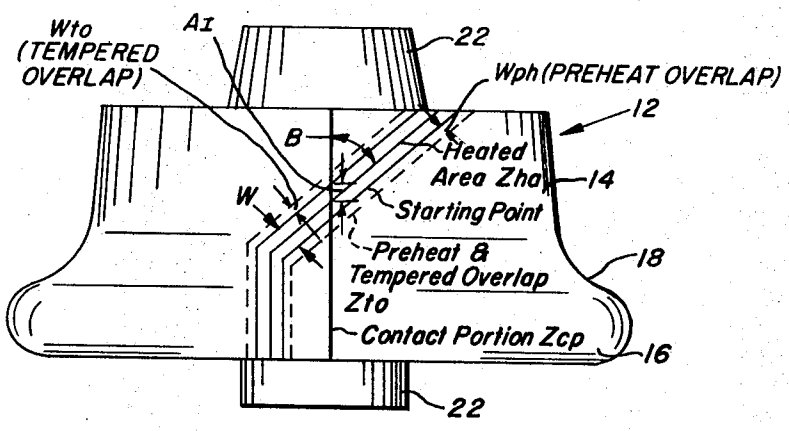


FIG. 1

FIG. 3



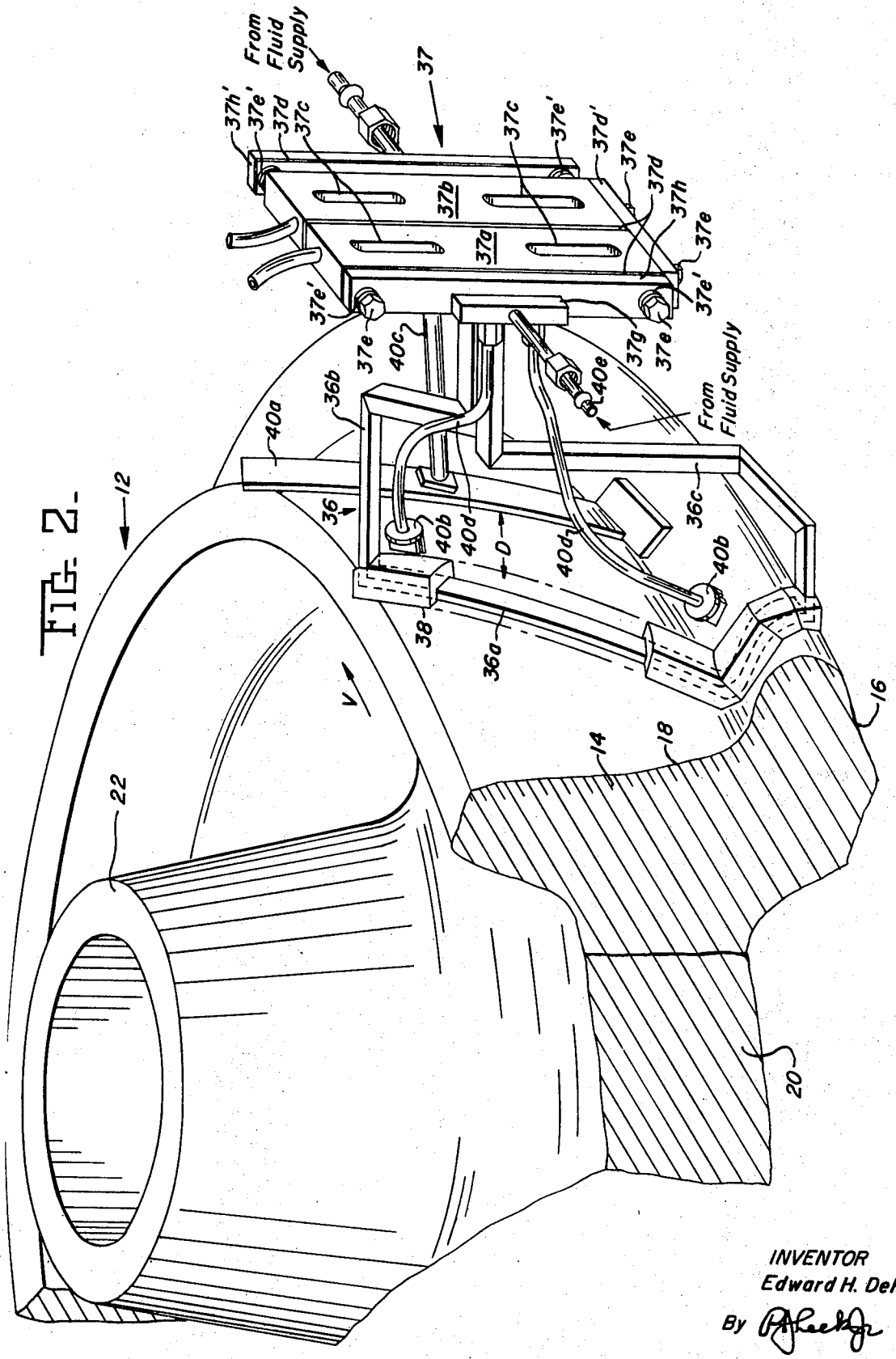
INVENTOR
Edward H. Dehn
By
Attorney

Oct. 6, 1970 E. H. DEHN 3,532,333

APPARATUS FOR AND METHOD OF CASE-HARDENING AN ARCUATE MEMBER

Filed Dec. 21, 1967 3 Sheets-Sheet 2

FIG. 2.



INVENTOR
Edward H. Dehn
By
Attorney

Oct. 6, 1970 E. H. DEHN 3,532,333

APPARATUS FOR AND METHOD OF CASE-HARDENING AN ARCUATE MEMBER

Filed Dec. 21, 1967 3 Sheets-Sheet 3

FIG. 4.

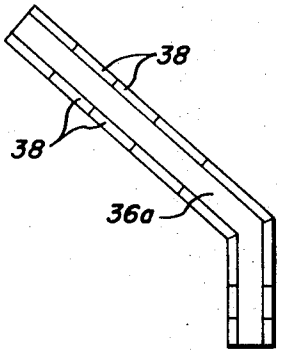


FIG. 4A.

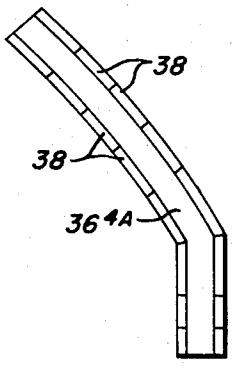
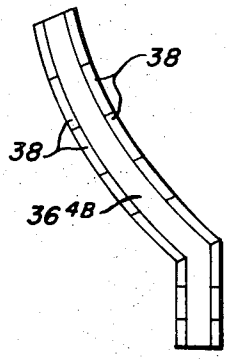


FIG. 4B



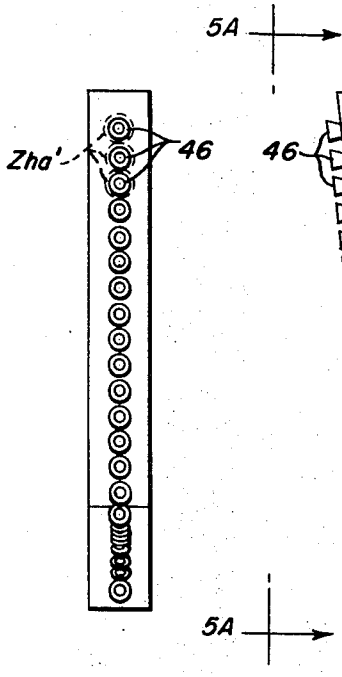


FIG. 5A.

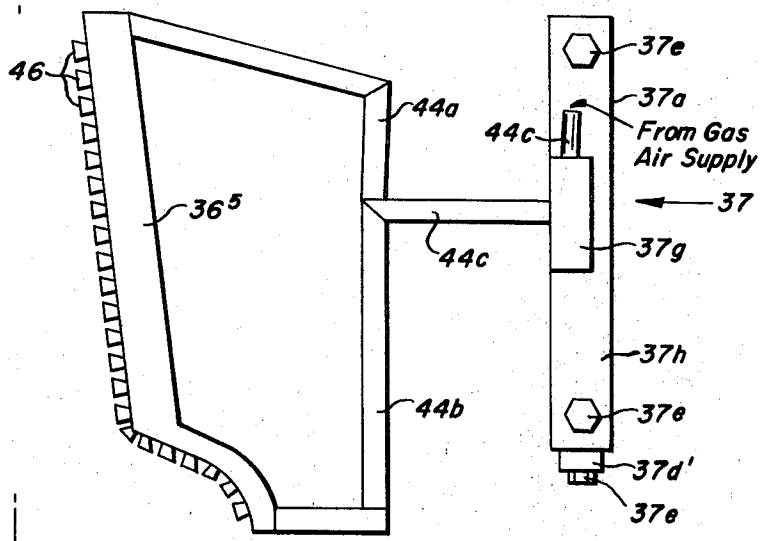


FIG. 5.

INVENTOR
Edward H. Dehn
By
Attorney

United States Patent Office

3,532,333
Patented Oct. 6, 1970

3,532,333

APPARATUS FOR AND METHOD OF CASE-HARDENING AN ARCUATE MEMBER

Edward H. Dehn, Oil City, Pa., assignor to United States Steel Corporation, a corporation of Delaware

Filed Dec. 21, 1967, Ser. No. 692,559
Int. Cl. C21d 1/66
U.S. Cl. 266—4 13 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to the surface hardening of arcuate members and, more particularly, to an improved apparatus for and method of surface hardening arcuate members having a continuous surface. The apparatus has means for supporting and rotating the arcuate member at a predetermined velocity, and heating means adjacent the supported arcuate member for case-hardening the continuous surface with a minimum width of tempered overlap.

The improved method includes the steps of supporting and rotating slowly the arcuate member at a predetermined velocity, heating the continuous surface to provide a moving heated area on the continuous surface, which moving heated area is disposed at an angle with respect to a contact portion (between the arcuate member and its track) to maximize the ratio of the area of the contact portion to the area of the intersection of the tempered overlap and the contact portion, minimize the width of the heated area and the area of the tempered overlap and quench the heated area to case-harden the heated area.

BACKGROUND OF THE INVENTION

Heretofore, arcuate members having a continuous surface provided with a contact portion, such as car wheels, brake wheels and the like, were case-hardened by heating the entire wheel (in a conventional gas, coal or oil fired furnace or in an induction heating coil) and then quenching the surface of the wheel which was to be case-hardened. The continuous surface of the wheel is the tread and sometimes a flange on the rim of the wheel. The contact portion is the moving substantially stragiht line contact between the rim of the wheel and the track upon which the rim rides. One disadvantage of the conventional method is the large electrical power and fuel requirements for heating such wheels. Further, the depth and location of the hardened case on the wheel was difficult to control uniformly, often resulting in the undesirable hardening and embrittling of inner portions of the wheel extending from the rim into the core or web and sometimes into the hub of the wheel, thus producing a hard brittle web rather than a tough ductile web. In addition the diameter of the wheels which can be case-hardened is limited by the conventional apparatus.

Conventional heat-treating apparatus is shown in the following United States patents:

U.S. Patent No.	Inventor	Issue date
1,276,106	Pease et al	Aug. 20, 1918
1,391,907	Schaffer	Sept. 27, 1921
1,697,068	Kenney	Jan. 1, 1929
1,204,327	Kenney et al	Mar. 5, 1929
2,068,913	Gregg	Jan. 26, 1937
2,596,345	Penrod	May 13, 1952
2,356,150	Denneen et al	Aug. 22, 1944
2,398,085	Denneen et al	Apr. 9, 1946
2,521,699	Denneen et al	Sept. 12, 1950
2,524,044	Denneen et al	Oct. 3, 1950
2,582,929	Gridley	Jan. 15, 1952
2,749,423	Bisterfield	June 5, 1956
2,759,085	Van Iperen	Aug. 14, 1956
2,777,041	Dustman	Jan. 8, 1957
2,785,263	Van Iperen	Mar. 12, 1957
2,810,054	Jones	Oct. 15, 1957
2,825,788	Loving	Mar. 4, 1958
2,828,397	Emerson	Mar. 25, 1958
2,820,466	Wishart	Jan. 21, 1958
2,857,154	Jones	Oct. 21, 1958
3,119,917	Dehn	Jan. 28, 1964

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 case-hardening an arcuate member having a continuous surface provided with a contact portion, which method and apparatus:

(1) require a minimal power or fuel requirement to case-harden the arcuate member,

(2) provide uniform control of the depth of and the location of the hardened case on the arcuate member,

(3) are adapted to case-harden arcuate members of any diameter, and

(4) provide a tough ductile core in the arcuate member, which core is unaffected by the case-hardening process and is not undesirably hardened or embrittled.

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 improved apparatus for surface or case-hardening an arcuate member having a continuous surface provided with a contact portion and having means for supporting and rotating the arcuate member at a predetermined velocity, and heating means adjacent the supported arcuate member for case-hardening the continuous surface with a minimum width of tempered overlap. The heating means is generally contoured to provide a moving heated area on the continuous surface and is disposed at an angle with respect to the contact portion to maximize the ratio of the area of the contact portion to the area of the intersection of the tempered overlap and the contact portion. The width of the heated area and the tempered overlap area is minimized, and quenching means are connected to a fluid source and disposed adjacent the heating means for quenching and case-hardening the heated area.

The improved method includes the steps of supporting and rotating the arcuate member at a predetermined velocity, heating the continuous surface to provide a mov-

ing heated area on the continuous surface, which moving heated area is disposed at an angle with respect to the contact portion to maximize the ratio of the area of the contact portion to the area of the intersection of the tempered overlap and the contact portion, minimizing the width of the heated area and the tempered overlap area, and quenching the heated area to case-harden the heated area.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

For a better understanding of this invention reference should be had to the accompanying drawings, wherein like numerals of reference indicate similar parts throughout the several views and wherein:

FIG. 1 is a side elevational view partially in vertical section of the improved case-hardening apparatus and a wheel being case-hardened;

FIG. 2 is a perspective view of the wheel being case-hardened and an induction heating means;

FIG. 3 is a side elevational view of the wheel being case-hardened and showing the heated area and the tempered overlap area;

FIG. 4 is a front view of the substantially straight line type of induction heating coil shown in FIGS. 1–3;

FIGS. 4A, 4B are views similar to FIG. 4 of alternative embodiments of the induction heating coil;

FIG. 5 is a front view of a substantially straight line type of heating torch; and

FIG. 5A is a side elevational view of the heating torch shown in FIG. 5 and taken from the left side of FIG. 5 along the line **5A—5A** of FIG. 5 in the direction of the arrows.

Although the principles of this invention are broadly applicable to case-hardening of arcuate members, this invention is particularly adapted for use in conjunction with the controlled low power induction heating or low fuel consumption type of heating of arcuate members to case-harden 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 surface or case-harden an arcuate member, such as a wheel **12** (FIGS. 1–3), having a continuous surface, suitably a rim **18** (FIGS. 1–3) of the wheel **12** having a tread **14** (FIGS. 1–3) and flange **16** (FIGS. 1–3). In addition, the wheel **12** has a core **20** (FIGS. 1, 2) and a hub **22** (FIGS. 1–3). The rim **18** is provided with a movable contact portion *Zcp* (FIG. 3), namely the substantially straight line contact between the rim **18** and the track (not shown) on which the wheel **12** rides.

For the purpose of supporting and rotating slowly the wheel **12** at a predetermined velocity V (FIGS. 1, 2), a table **26** (FIG. 1) carries a turntable **28** (FIG. 1) mounted on a shaft **30** (FIG. 1) journaled in a bearing **32** (FIG. 1) in the table **26** and driven by a gear-reduction unit **34** (FIG. 1) and a motor **35** (FIG. 1).

Referring now to FIGS. 1, 2, a heating means, such as an induction heating apparatus **36**, is disposed adjacent the supported rotating wheel **12** for heating the rim **18** above the critical temperature (as hereinafter explained) for the particular metal in the wheel **12** so that the rim **18** may be later quenched and case-hardened with a minimum width *Wto* of tempered overlap zone *Zto* (FIG. 3) as hereinafter described. The induction heating apparatus **36** has an induction heating coil **36***a* (FIGS. 2, 4) connected by leads **36***b*, **36***c* (FIG. 2) to a hollow block **37**, FIG. 2, fluid cooled as by water or the like.

This fluid-cooled block **37** has two hollow halves **37***a* (FIG. 2) and **37***b* (FIG. 2) each provided with elongated mounting slots **37***c* (FIG. 2) to facilitate the mounting of the coil **36***a* adjacent the wheel **12**. In order to electrically insulate the two halves **37***a*, **37***b* of the block **37** from each other and to integrate such blocks **37***a*, **37***b*, an insulating spacer **37***d* (FIG. 2) formed of a dielectric material, such as Bakelite or the like, is disposed therebetween and the half blocks **37***a*, **37***b* are mounted on an insulating block **37***d'* (FIG. 2), suitably Bakelite or the like, by bolts **37***e* extending through the insulating block **37***d'* and threadable into the half blocks **37***a*, **37***b*. Side mounting plates **37***h*, **37***h'* (FIG. 2) are mounted on the half blocks **37***a*, **37***b* by bolts **37***e* (FIG. 2) and are insulated and spaced from their adjacent half blocks **37***a*, **37***b* respectively by insulating spacers **37***d* (FIG. 2), insulating washers **37***e'* (FIG. 2), and an insulating sleeve (not shown). Bakelite is the trade name of a dielectric material manufactured by Union Carbide Corporation, New York, N.Y.

Referring now to FIG. 1, each half block **37***a*, **37***b* is mounted on an individual terminal block **33***a* of bus bars **33***b*, **33***c* respectively by means of bolts **37***e* extending through the slots **37***c* (FIG. 2) and threading into threaded holes **33***d* in the terminal blocks **33***a*. The bus bars **33***b*, **33***c* in turn are integrated by a dielectric block **33***e*, which block **33***e* is mounted on a bracket **37L** by means of bolts **37***e* extending through an insulating washer **33***f*, an insulating sleeve **33***g* in the bracket **37L**, the dielectric block **33***e* and threading into the terminal blocks **33***a*. The bracket **37L** is secured to the table **26** by bolts **37***e* and nuts **37***f*. In order to electrically insulate the terminal blocks **33***a* from each other and also the bus bars **33***b*, **33***c* from each other, an insulating spacer **33***h* is disposed therebetween. The bus bars **33***b*, **33***c* are connected by conventional means (not shown) to a power source, such as a transformer (not shown). In order to cool the bus bars **33***b*, **33***c*, half blocks **37***a*, **37***b*, etc., a fluid, such as water, flows from a fluid supply indicated by the legend "FROM FLUID SUPPLY" into channels **33***i* provided in the bus bars **33***b*, **33***c* and in the terminal blocks **33***a*; through connecting loops **33L** to the half blocks **37***a*, **37***b*; and thence through the leads **36***b*, **36***c* to the coil **36***a*. For the purpose of integrating the mid portions of the bus bars **33***b*, **33***c* insulating blocks **33***m* are secured by bolts **37***e* which thread into nuts **33***n* brazed to the channels **33***i*.

The coil **36***a* is generally contoured to the shape of the tread **14** and the flange **16**, as shown in FIGS. 1, 2, to provide a heated area *Zha* (FIG. 3) on the tread **14** and flange **16**. As shown in FIG. 1, the smaller radius tread **14** is spaced at a distance d_1 from the coil **36***a* while the larger radius flange **16** is spaced a distance d_2 from the coil **36***a*. The distance d_1 is greater than the distance d_2. The coil **36***a* is disposed at an angle B (FIG. 3) with respect to the contact portion *Zcp* to maximize the ratio of the area of the contact portion *Zcp* to the area of the tempered overlap *Zto*.

In order to minimize the width W (FIG. 3) of the heated area *Zha* and the resultant tempered overlap area *Zto*, intensifying means, such as the intensifiers **38** (FIGS. 1, 2, 4) are mounted on the coil **36***a*. These intensifiers or flux concentrators **38** are formed of a ferromagnetic plastic, for example, powdered iron dispersed in plastic binders as disclosed in United States Pat. 2,777,041, issued Jan., 1957 to H. C. Dustman or of the type known as Ferrotron and manufactured by The Polymer Corporation, Reading, Pa.

The means utilized for quenching the heated area *Zha* is a quenching means, such as the quench head **40***a* (FIGS. 1, 2). This spray or quench head **40***a* is connected by a conduit **40***c* (FIGS. 1, 2) (attached to the side mounting plate **37***h'* on the fluid-cooled block **37**, as by welding) and extending to a fluid supply, indicated by the legend "FROM FLUID SUPPLY." The fluid employed in the quench head **40***a* may, for example, be water, oil

or a mixture of water and "Aqua Quench," a water soluble, resinous material used as an additive for water quenching systems to provide a quenching rate between that of water and the fastest quenchable oil and manufactured by the E. F. Houghton & Company, Philadelphia, Pa. The quench head **40***a* is disposed a distance D (FIG. 2) from the coil **36***a* to provide a soaking zone or soaking time for the wheel **12** and is disposed below the coil **36***a* to prevent adverse cooling of the already heated portion of the rim **18** of the wheel **12**.

For the purpose of cooling the intensifiers **38** on the coil **36***a*, spray heads **40***b* (FIGS. 1, 2) are directed at the intensifiers **38** and connected by lines **40***d* (FIGS. 1, 2) through a block **37***g* (FIGS. 1, 2) attached to the mounting plate **37***a* as by welding, to a line **40***e* leading to a fluid supply (indicated by the legend "FROM FLUID SUPPLY") and suitably air, water or the like. The intensifiers **38** are cooled below a temperature in the range of about 450–500° F., the breakdown temperature, by a fine atomized mist from the spray heads **40***b*.

The fluid from the quenching head **40***a* and spray heads **40***b* is collected in a tray **39** (FIG. 1) mounted by means of resilient spacers **39***a* (FIG. 1) on the table **26**.

EXAMPLES

If the wheel **12** is composed of a type 1050 steel having about 0.50% (by weight) carbon and 0.91% manganese, the coil **36***a* must raise the temperature of the moving heated area *Zha* (FIG. 3) above a temperature of about 1650° F. to properly austenitize the wheel **12**. Prompt cooling by the quench head **40***a* below about 200° F. will provide a proper martensite content with a Rockwell hardness of about **62**.

When a wheel **12** is formed, for example, of a modified type 4150 alloy steel having by weight a carbon content of about 0.55%, a manganese content of about 0.60%, a chromium content of about 1.03%, a molybdenum content of about 0.19% and a nickel content of about 0.36%, the coil **36***a* raises the moving heated area *Zha* (FIG. 3) above a temperature of about 1550° F. and upon self-quenching through the mass of the wheel **12** below about 450° F., a Rockwell hardness of about **55** is produced.

In the tempered overlap zone *Zto* (FIG. 3) the preheat beyond the heated zone *Zha* reheats the already case-hardened rim **18**, up to, for example, a temperature of about 600° F. where in the case of the type 1050 steel and type 4150 steel the respective hardnesses are reduced to about 48 Rockwell and about 51 Rockwell.

From a consideration of FIG. 3 it is apparent that by disposing the tempered overlap *Zto* at an angle B with respect to the contact portion *Zcp*, the ratio of the area of the contact portion *Zcp* to the area of the intersection AI (FIG. 3) of the tempered overlap zone *Zto* and the contact portion *Zcp* is maximized and wear at the weak point (i.e. the intersection AI of the tempered overlap zone *Zto* and the contact portion *Zcp*) is minimized.

It has been found that the best results are obtained when the angle B is in the range of about 10° to 80°.

ALTERNATIVE EMBODIMENTS

It will be understood by those skilled in the art that alternatively, as shown in FIGS. 4A, 4B, the induction heating coil may be arcuate convex as illustrated by the coil 36^{4A} (FIG. 4A) or arcuate concave as exemplified by the coil 36^{4B} (FIG. 4B). In FIGS. 5, 5A a gas-fired torch 36^{5} is provided with intensifier means, such as divergent nozzle burners **46** to provide the minimized width W (FIG. 3) for the moving heated area *Zha*. The torch 36^{5} is connected by lines **44***a*, **44***b*, **44***c* (FIG. 5) through the block **37***g* (or attached to a half block **37***a* or **37***b*) to a gas air supply indicated by the legend "FROM GAS AIR SUPPLY." As shown in FIG. 5A, each burner **46** provides an overlapping heated area *Zha'* (indicated by the overlapping dotted circles). This overlapping heated area Zha^{1} can also be produced by cylindrical or converging nozzle burners **46**.

METHOD

It will be understood from the above description that an improved method is also provided for surface hardening an arcuate member or wheel **12** (FIGS. 1–3) having a continuous surface or rim **18** provided with a contact portion *Zcp* (FIG. 3). This method includes the steps of supporting and slowly rotating the arcuate member or wheel **12** (FIG. 1) at a predetermined velocity (FIGS. 1, 2), heating the continuous surface **18** (FIGS. 2, 3, 5A) to provide a moving heated area *Zha* (FIG. 3) on the continuous surface **18**, which moving heated area *Zha* is disposed at an angle B with respect to the contact portion *Zcp* to maximize the ratio of the area of the contact portion *Zcp* to the area of the intersection AI (FIG. 3) of the tempered overlap *Zto* and the contact portion *Zcp*, minimizing the width W of the heated area *Zha* and the width *Wto* (FIG. 3) of the tempered overlap area *Zto*, and quenching the heated area *Zha* to case-harden the heated area *Zha*.

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** (FIGS. 1–4) for and an improved method of case-hardening an arcuate member **12** having a continuous surface **18** provided with a contact portion *Zcp*, which apparatus **10** and method require minimal power or fuel consumption to case-harden the arcuate member **12**, provide uniform control of the depth and the location of the hardened case on the arcuate member **12**, are adapted to case-harden arcuate members **12** of any diameter, and provide a tough ductile core **20** in the arcuate member **12**, which core **20** is unaffected by the case-hardening process and is not undesirably hardened or embrittled.

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 continuous surface provided with a contact portion having an axis of rotation and having:

(a) means for supporting and slowly rotating said arcuate member at a predetermined velocity, and

(b) heating means adjacent said supported arcuate member for case-hardening said continuous surface with a minimum width of tempered overlap,

(1) said heating means being generally contoured to provide a moving heated area on said continuous surface and disposed at an acute angle with respect to said axis of rotation of said contact portion to maximize the ratio of the area of said contact portion to the area of the intersection of said tempered overlap and said contact portion,

(2) intensifier means on said heating means to minimize the width of said heated area and said tempered overlap area, and

(3) quenching means connected to a fluid source and disposed adjacent said heating means for quenching and case-hardening said heated area.

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

3. The apparatus recited in claim **1** wherein said heating means is a gas-fired torch connected to a gas-air source.

4. The apparatus recited in claim **2** wherein said intensi-

fier means on said induction coil minimizes the width of the magnetic field of said induction coil.

5. The apparatus recited in claim 3 wherein said intensifier means on said gas-fired torch is a nozzle burner.

6. The apparatus recited in claim 1 wherein said heating means is substantially straight.

7. The apparatus recited in claim 1 wherein said heating means is substantially arcuate convex with respect to a longitudinal axis of said heating means.

8. The apparatus recited in claim 1 wherein said heating means is substantially arcuate concave with respect to a longitudinal axis of said heating means.

9. A method for surface hardening an arcuate member having a continuous surface provided with a contact portion having an axis of rotation and including the steps of:

(a) supporting and slowly rotating said arcuate member at a predetermined velocity,

(b) heating said continuous surface to provide a moving heated area on said continuous surface and disposed at an acute angle with respect to said axis of rotation of said contact portion to maximize the ratio of the area of said contact portion to the area of the intersection of said tempered overlap and said contact portion,

(c) minimizing the width of said heated area and said tempered overlap area, and

(d) quenching said heated area to case-harden said heated area.

10. The method recited in claim 9 wherein said continuous surface is induction heated.

11. The method recited in claim 9 wherein said continuous surface is torch heated.

12. The apparatus recited in claim 1 wherein said quenching means is a quench head disposed in spaced relation ahead of said heating means.

13. The apparatus recited in claim 1 and having a spray head for cooling said heating means.

References Cited

UNITED STATES PATENTS

2,085,790	7/1937	Campbell	266—5
2,414,362	1/1947	Denneen et al.	266—4
2,424,816	7/1947	Groven et al.	219—10.59
2,477,029	7/1949	Wood	266—4 X
2,512,893	6/1950	Gehr	266—4
2,882,191	4/1959	Van Swaal	266—4 X

FOREIGN PATENTS

225,333	1923	Great Britain.

J. SPENCER OVERHOLSER, Primary Examiner

R. S. ANNEAR, Assistant Examiner

U.S. Cl. X.R.

148—150, 151, 153