Oct. 5, 1965 P. F. GOOD 3,210,223

HARDENING AND STRAIGHTENING METHOD AND APPARATUS FOR USE WITH FLANGED AXLES

Original Filed Jan. 28, 1960 3 Sheets-Sheet 1

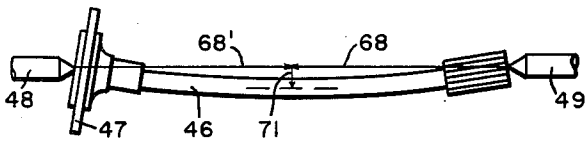


Fig. 1.

Fig. 2.

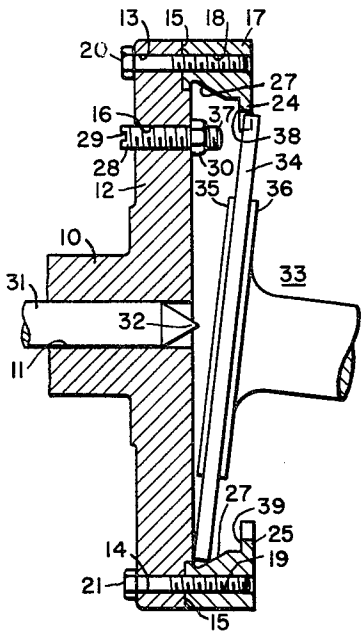
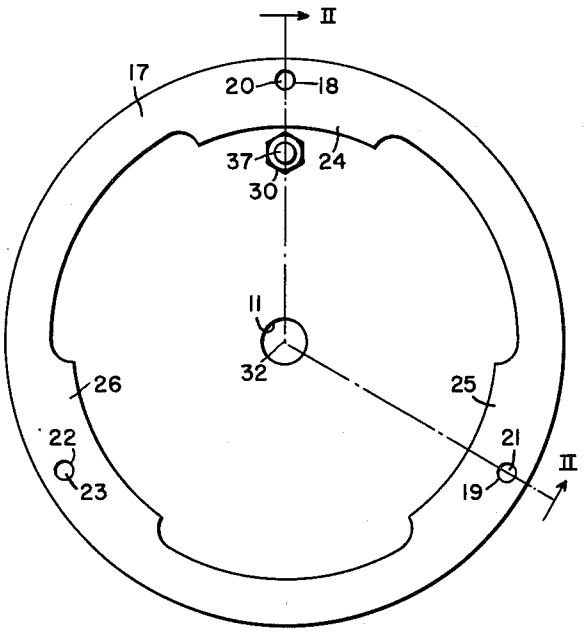


Fig. 3.



WITNESSES

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Fig. 4.

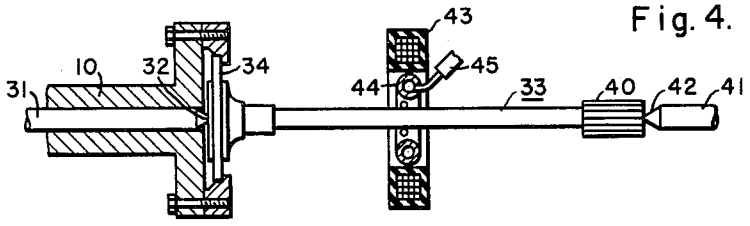


Fig. 5.

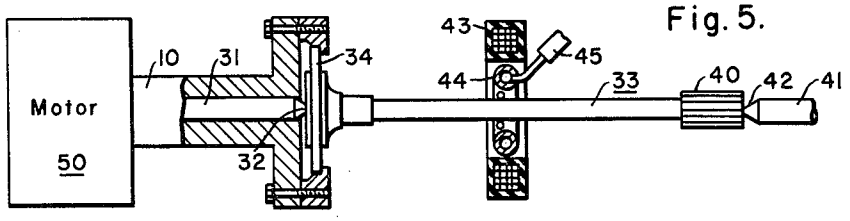


Fig. 6.

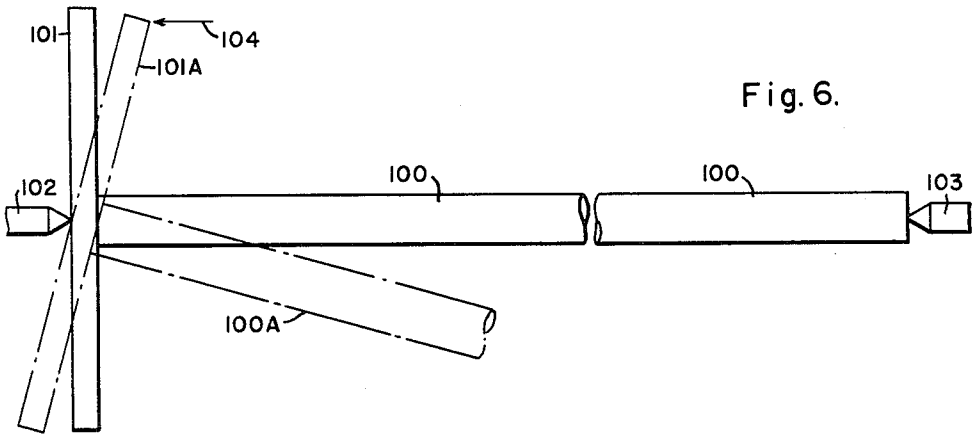


Fig. 7.

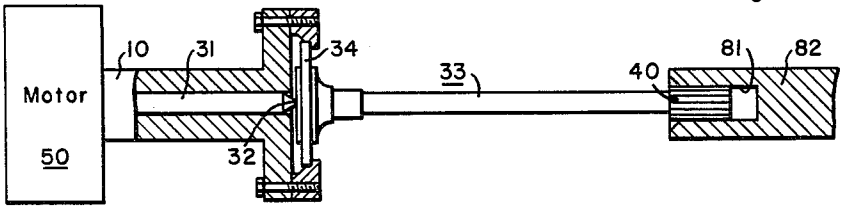


Fig. 9.

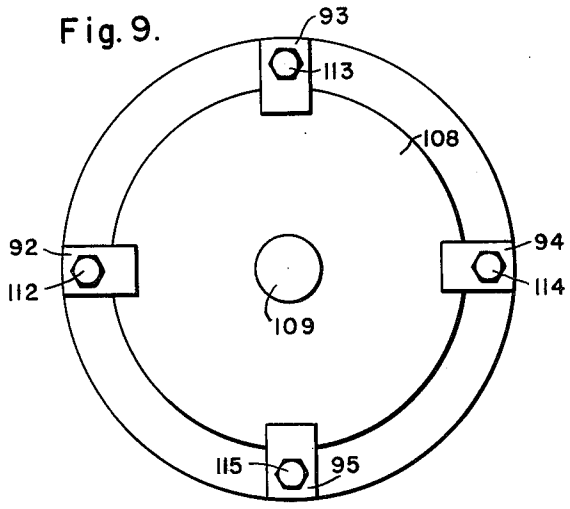
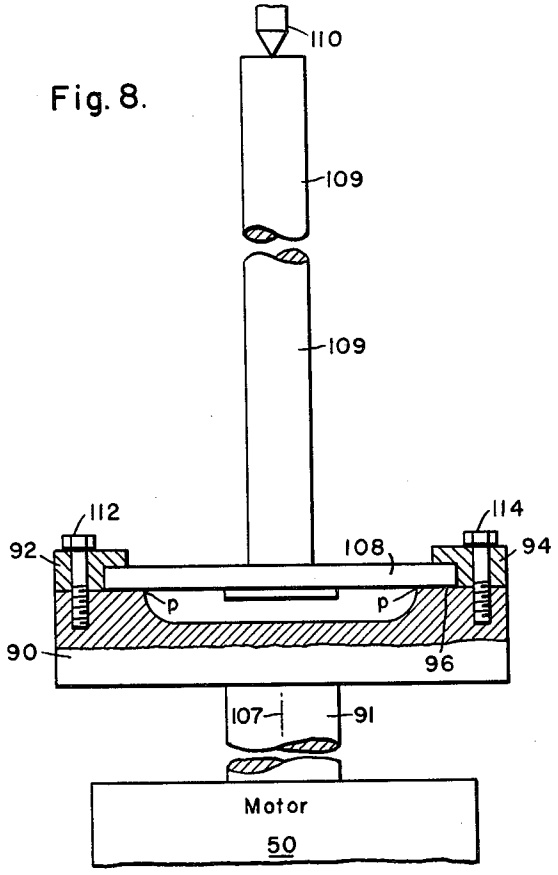

93
113
108
92
94
112
114
109
115
95

Fig. 8.


110
109
109
112
114
92
108
94
p
p
90
96
107
91
Motor
50

United States Patent Office

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3,210,223

HARDENING AND STRAIGHTENING METHOD AND APPARATUS FOR USE WITH FLANGED AXLES

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Continuation of application Ser. No. 5,143, Jan. 28, 1960. This application Nov. 20, 1962, Ser. No. 239,415
16 Claims. (Cl. 148—131)

This application is a continuation of my prior application Serial No. 5,143, filed January 28, 1960, which application was a continuation-in-part of application Serial No. 651,391, filed April 8, 1957, both now abandoned.

The invention relates to straightening and hardening methods and apparatus, and more particularly to hardening straightness inducing methods employing heat-treating, and to apparatus for heat-treating flanged axles.

In heat-treating or hardening axles or shafts difficulty is frequently encountered as a result of distortion or bending of the shaft while it is being heated, or distortion, warpage, or want of conformation to definite specifications resulting from strains which are set up in the axle or shaft during its rapid cooling.

Prior art devices for overcoming these difficulties may be generally divided into two groups. One group of prior art devices is concerned with straightening the shaft or axle after the warpage has occurred. The straightening is a hand-operating process and is therefore quite costly and time-consuming.

A second group of prior art devices attempts, without success, to prevent the warpage which may occur during either the heating or cooling portion of the heat-treating process, or both. One such prior art device employs a plurality of rollers at spaced intervals along the rotating shaft to prohibit warpage and distortion, while another prior art device employs a plurality of spaced jaws for holding the shaft in alignment during quench cooling. Still other prior art apparatus for use with flanged shafts applies axial force to the axle in a manner which may tend to maintain the flange against abutting support means, but the axial force creates moments of forces in the axle which tend to bend the axle, and furthermore the axial force creates moments of forces which add to and aid bending and warping forces released in the axle by heating thereof.

According to the method of the instant invention the axle to be straightened or hardened while assuring a maximum degree of straightness has its flange rigidly clamped at mounting and during the heating and cooling portions of the hardening processes, in a manner urging the axle flange toward and preventing movement of the axle flange out of its normal position with respect to the straight axis of the axle, while utilizing the flange as a lever for providing for the production of forces or moments in the axle tending to straighten same if initially bent and/or to counteract those unequal forces and stresses which occur across the cross-section of the axle tending to warp the axle during heat-treatment; which latter forces may result from either pre-hardening straightening operations or stresses set up during the hardening or treating process. In some embodiments of the invention, the adjacent mounting or centering means serves as a fulcrum in the setting up of these flange clamping forces which assure flange position integrity and oppose bending and warping forces.

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Furthermore, apparatus for practicing the method of the instant invention mounts the axle to be heat-treated without applying any force, or any significant force, along the longitudinal axis of the axle in a manner which would create bending moments in the axle, and also create moments of forces which would add to and aid warping forces released in the axle as a result of heating.

Accordingly, it is a primary object of this invention to provide a new and improved hardening and straightening method for use with flanged axles.

Another object is to provide a new and improved method of heat-treating a flanged axle wihch limits to a greater degree than heretofore critical distortion of the axle during such heat-treating.

Another object is to provide a new and improved method of maintaining the straightness of flanged axles during heat treatment, in which clamping forces applied to the flange holds same perpendicular to the normal straight axis of the axle as well as utilizes the flange as a lever to set up forces in the axle which oppose bending or warping thereof.

Another object of the invention is to provide a new and improved method particularly suitable for maintaining the straightness of flanged axles during induction hardening processes.

A further object is to provide new and improved apparatus for use in heat-treating or hardening a flanged axle without applying any force, or without applying any significant force along the longitudinal axis of the axle which would tend to aggravate bending or warping thereof.

Other objects and advantages of the instant invention will become apparent after reading the following specification in connection with the accompanying drawings, in which:

FIGURE 1 illustrates exaggerately the bending of the shaft or axle which tends to occur when the axle is supported at the ends by conventional prior art means during hardening, and also illustrates the bending moment of force in the axle resulting from forces applied to the axle along the longitudinal axis thereof;

FIG. 2 is a cross-sectional view of apparatus for holding or clamping the flange of the axle to be hardened during the heat-treating process according to the method and apparatus of the instant invention;

FIG. 3 is an end view of the flange holding apparatus of FIG. 2;

FIG. 4 is a view of flanged axle supporting apparatus and heating and quenching means suitable for practicing the method of the invention;

FIG. 5 is a view of the flanged axle supporting and rotating apparatus, and an induction heating coil and quenching means arranged according to the instant invention, and illustrating the straightness which is maintained when a flanged axle is treated according to the method of the instant invention;

FIG. 6 illustrates leverage forces at the flange which set up moments of forces in the axle which oppose bending and warping forces, while the axle is mounted according to the method of the instant invention;

FIG. 7 shows a method of and apparatus for mounting the axle according to the preferred embodiment of the invention, in which no axial forces are applied between the ends of the axle;

FIG. 8 is a view of a third embodiment of the invention, in which the shaft to be hardened, straightened, or

both may be mounted in a vertical position, and which requires no centering pin or other centering means at the flange end of the axle; and

FIG. 9 is an additional view of the flange clamping portion of the mounting means of FIG. 8.

Particular reference is made now to the drawings, in which like reference characters are used throughout to designate like parts, for a more complete understanding of the invention, and in particular to FIG. 1 thereof. Where an axle **46** to be hardened is merely mounted between centering means **48** and **49** at the ends thereof and progressively heated and cooled along the length thereof, the axle may be originally bent and substantial bending or warping tends to occur during the heat-treating, and there are no forces active in the axle to permit the bending or warping or to restore the axle to a straight condition. Such a warped condition is shown exaggeratedly in FIG. 1; the flange **47** being dislocated with respect to the normal straight axis defined by centers **48** and **49** as a result of the bent condition of the axle.

Furthermore, a component of force **71** in a direction to bend the axle is set up in the axle **46** of FIG. 1 as a result of axial force applied between the ends of the axle. Assume for example that arrow **68** illustrates the force applied to the splined end of the axle along what should be the longitudinal axis; an equal force **68'** exists in the opposite direction. These forces create moment **71** in a direction transverse to the longitudinal axis and in a direction to bend the axle; for a cold axle, for a given axle material, and given dimensions of length and diameter of the axle, the magnitude of moment **71** is roughly proportional to the axial force and the distance the center of the axle is from the true or straight longitudinal axis. An analysis of stresses in bars and columns resulting from longitudinal forces may be found in the literature of the art, for example in Marks, "Mechanical Engineers Handbook," 5th Ed., McGraw-Hill Book Co., 1951, Ch. 5 on Strength of Materials.

Furthermore, heating of the axle **46** of FIG. 1 at any point along the length thereof may create a band of hot and soft metal, which may weaken the axle in this area, and tend to increase the effect of a moment similar to moment **71** to bend and warp the axle.

Still further, heating of the axle **46** may release random forces in the axle resulting from stresses "sealed in" during previous operations on the axle; axial force applied to the axle create moments which aid and add to these random forces which are frequently in directions to bend and warp the axle.

Particular reference is made now to FIG. 2. The support member **10**, which it is understood is rotatably mounted on any suitable means, not shown, has a preferably circular bore **11** therein, for purposes to be hereinafter made more clearly apparent.

The support member **10** has an annular flange portion **12** on the end thereof, preferably formed integrally therewith, the flange portion **12** having a plurality of bores at spaced intervals around the periphery thereof near the outer edge thereof, two of the bores being shown in FIG. 2 and designated **13** and **14**. The flange portion **12** has a cut-away portion **15** extending around the periphery thereof on the right-hand surface as viewed in FIG. 2, and the flange portion **12** also has a threaded bore **16** therein for purposes to be hereinafter made more clearly apparent. Mounted upon the flange portion **12** of support **10** in the cut-away portion **15** thereof is a ring or cam member **17**, the ring or cam member **17** having a plurality of threaded bores therein adapted to be in substantial alignment with the bores in portion **12** while member **17** is mounted on the flange portion **12**, two of the threaded bores in member **17** being designated **18** and **19** and shown in FIG. 2. A plurality of bolts, two of which are shown at **20** and **21** in FIG. 2, extend through the bores **13** and **14** in portion **12** and have their threaded ends in threaded engagement in the bores **18** and **19**

respectively in member **17**. The other of the bores in member **17** is shown in FIG. 3, and is designated **22**, with bolt **23** shown therein. The member **17** has three inwardly extending lip portions **24**, **25** and **26**, FIG. 3, and the interior surface of the cam member **17** flares or tapers outwardly as the surface extends toward the adjacent member portion **12**, the flaring or tapering portion of the cam surface being shown at **27**, FIG. 2.

The aforementioned threaded bore **16** in flange portion **12** is seen, FIG. 2, to have in threaded engagement therein the screw **28** having the slot **29** in the outer end thereof, the screw member **28** extending through the flange portion **12** into the area enclosed by the ring or cam member **17**, screw member **28** having in threaded engagement on the end thereof adjacent member **17** a locking nut **30**. The aforementioned bore **11** in support member **10** is seen, FIG. 2, to have disposed therein a centering support and locking pin **31** having a tapered end portion **32**. The locking pin **31** may be moved by any convenient means, not shown, such for example as a hand wheel, or the locking pin **31** may be air-operated if desired.

The axle to be treated or hardened is shown at **33**, with the shaft or spindle portion thereof broken away for convenience of illustration, the axle **33** having a large flange **34** which, in the illustration shown, has opposite annular face portions which lie in a plane perpendicular to the longitudinal axis of the axle, at the left-hand end thereof as seen in FIG. 2, and having adjoining rib or raised portions **35** and **36**.

In mounting the axle to be hardened in the apparatus for holding the flange thereof, the operator rests the flange **34** of the axle **33** on the lower portion of the sloped cam surfaces **27** of adapter ring **17**, for example in the position shown in FIG. 2. The operator then raises the other or splined end of the axle **33** to a horizontal position. As the axle is raised to the horizontal position, the upper portion of the flange of the axle presses against the aforementioned screw member **28**, the inner or right-hand end **37** of which serves as a positioning pin, and provides a fulcrum for causing the lower portion of the flange **34** to ride or slide upward on the sloping cam surface **27**, positioning the flange **34** properly in the adapter ring or cam member **17** in a position whereat portions of an annular surface of one face of the flange **34** rest adjacent inner surfaces of the aforementioned lips **24**, **25** and **26**, which surfaces lie in a plane perpendicular to the axis of pin **31** and two of which inner surfaces being shown in FIG. 2 and designated **38** and **39**. The operator of the apparatus thereafter moves the locking pin **31** until the end portion **32** thereof is forced tightly against the center of the flange or adjacent end of the axle **33** with a force of, for example, 1000 pounds, and thereby clamps or locks the flange **34** tightly against the aforementioned lip inner surfaces including surfaces **38** and **39**, to provide for creation of forces strongly urging the axle toward and maintaining the axle in a substantially straight position during the hardening process. FIG. 4 shows flange **34** in its clamped position. As will be apparent from a study of FIG. 4, since the clamping forces applied to the flange are large, a differential in the forces on the flange exists when there is a deviation of the axle from a straight condition upon initiating the clamping, so that a differential exists in the forces on the flange at substantially diametrically opposite points which results in the creation of a moment of force in the axle flange and shaft portions which opposes the deviation and urges same to assume their normal straight-axle attitudes. When the axle flange **34** is disposed perpendicular to the normal straight axis of the axle and in equally firm engagement with all of the lips **24**, **25** and **26** of member **10**, the tapered end portion **32** of the mounting or centering means acts as a fulcrum for the axle flange **34**. If during the subsequent heating and cooling operations the axle tends to bend downward in a manner similar to that illustrated in FIG. 1, the instant

force applied to the top of the flange 34 in a left-hand direction holds it perpendicular and utilizing the flange as a lever, tends to hold the axle in a straight position, opposing bending thereof. After the flanged end of the shaft to be hardened is mounted as shown in FIG. 4, the operator positions a center 42 against the splined end 40 of the axle. The center 42 is aligned with pin 31 and acts as a lateral guide or radial constraint for the adjacent end of the axle, the axle having a conical centering hole, not shown, in the end thereof. The centering or radially locking pin 41 having center 42 may be manually or pneumatically fed or operated by any convenient means, not shown. Only a small force, for example, 25 or 30 pounds or less, may be applied to 41, as by spring tension, once the end 42 is in centering position. The method and apparatus of this embodiment of the instant invention eliminates the necessity for large forces applied along the longitudinal axis of the axle, which would create a bending component in the axle and which would tend to aggravate warping or bending by aiding warping or bending forces once these latter forces were set up in the axle. As will be readily understood by those skilled in the art, if the axle has previously been straightened to some extent, heating the metal of the axle will release forces which tend to distort the axle to its previous bent or warped shape or condition.

Movably disposed around the axle 33 is an induction coil generally designated 43 for heating the adjacent portion of the axle 33. A suitable source of potential, not shown, is connected to coil 43 for energizing the same. A quenching ring 44 is preferably nestled into the induction coil 43, and may be formed integrally therewith. The quenching or cooling ring 44 has flexible hose 45 for bringing a supply of quenching fluid to the ring, and the coil 43 and ring 44 are movably disposed with respect to axle 33, being movable along substantially the entire length thereof.

In the practice of the method of the invention according to the illustration of FIG. 4, the axle 33 has the ends thereof mounted between pins 31 and 41 while flange 34 is strongly urged toward and/or securely held or clamped in a plane perpendicular to the normal straight longitudinal axis of the axle as defined by such pins, the lips 24, 25 and 26 of member 17 (FIGS. 2 and 3), and the large force applied to the flange by way of pin portion 32 to clamp the flange against ring member 17 strongly urging the flange toward and preventing movement of the flange from the perpendicular during the hardening process while providing for the creation of forces in the axle which tend to straighten same when initially bent and to oppose warping of the axle when straight. The induction coil 43 and quench ring 44 are progressively moved along the length of the axle, heating and cooling the axle including the flanges to thereby harden it. Clamping of the flange provides for setting up forces within the axle which induces straightening and opposes forces which would tend to bend or distort the axle and its flange relative to the normal straight axis during the heating or cooling thereof, thereby avoiding an undesirable result such for example as that illustrated in FIG. 1, where a shaft 46 having flange 47 and mounted by conventional means 48 and 49 is seen to be bent and distorted following the hardening or tempering operation.

With reference to prevention or minimizing distortion of the axle shaft during heat-treating by the present method and apparatus, when an axle is cold straightened, enough force must be applied to stress the outer fibers of the axle beyond the elastic limit or the metal, otherwise after the force is removed the axle would merely spring back to its original bent position. During this cold straightening operation, the outer fibers on the convex side of the axle, that is the convex side before applying the cold straightening force, are stressed such that they yield in compression, and the fibers on the concave side yield in tension. Assume, by way of description, that while using the method of the instant invention, an axle which has been previously subjected to a cold straightening operation is being hardened, and that the portion of the axle adjacent coil 43, FIG. 4, has been heated. The outer fibers of the axle may become very hot while the inner section of the axle remains relatively cool. The strength of the outer fibers is reduced drastically, and this tends to upset the equilibrium of the frozen-in cold-straightening stresses in the axle and tends to permit it to return to its original bent shape. However, the narrow band of heated metal underneath the coil is relatively thin, and the clamping force applied to the flange transmitted to the thicker and relatively strong cold section of the axle resists this tendency for the axle to bend, thereby acting to hold the axle straight during the hardening process.

Particular reference should be made now to FIG. 5. The apparatus of FIG. 5 is similar to that of FIG. 4, with the addition of motor or other means 50 operatively connected to member 10 for rotating member 10 and the attached axle 33 during the heating and quenching process at any suitable speed, for example, 100 to 400 r.p.m.

Reference is made to FIG. 6 which illustrates the operation of axle straightness-inducing forces of the apparatus of FIGS. 3, 4 and 5 in further detail. Assume a shaft or axle 100 to be heat-treated having at one end thereof a flange 101 which it is desired be perpendicular to the straight longitudinal axis of the shaft, which in turn is desired to be straight, as shown mounted between end-centering supports 102 and 103. The axle or shaft 100 is shown broken at about the center of the spindle portion thereof to assist in illustrating the forces which are at work. Let it be assumed that the shaft 100 is not being rotated but is merely stationary. Assume now that the shaft is initially bent in the center thereof prior to the heat-treatment of the present method and apparatus and that its shaft occupies a position such as shown by the dashed lines 100A with the flange 101 in position 101A as shown by the dashed lines. Now assume for purposes of explanation that the shaft is actually broken in the middle as shown by the sketch. Utilizing the elementary principles of levers, if a force is applied at the point and in a direction indicated by the arrow 104 it will be apparent that this force applied at 104 with the point of 102 acting as a fulcrum would move the shaft portion 100 back into horizontal position, since the portion of the flange 100 extending above the shaft would act as a simple lever. It is apparent then that, for a non-rotating axle, a force constantly applied to the top of the flange in the direction shown by arrow 104 tends to return the flange 101 to a perpendicular position and the shaft 100 to a horizontal position. It will be understood that in the apparatus of FIGS. 2 and 3 the lips 25 and 26, FIG. 3, would limit movement of the axle flange 34 and define its perpendicular position relative to the axis of the aligned end supports for the axle, and thereby also the extent of upward movement of the axle shaft portion 33.

Now let it be assumed that the shaft 100, FIG. 6, rotates a mere 90° and stops. Assume again that the shaft is initially bent downwardly in the manner illustrated by the shaft position 100A. Again a force 104 applied to the top of the flange tends to restore it to the perpendicular, and utilizing the flange as a lever, tends to restore the axle 100 to a horizontal position. In fact, the shaft 100 can be rotated to any setting around 360 degrees, stopped, and the exemplified force applied at the top of the flange 101 will tend to restore it to the perpendicular and, utilizing that portion of the flange as a lever, tend to raise the central portion of the axle 100 if the central portion is bent or warped downward.

Assume now by way of description that the flange is substantially completely clamped around the entire periphery thereof by means exerting a force or forces in a left-hand direction corresponding to the direction

indicated by arrow **104**, i.e. in a direction parallel to the alignment axis of the end-centering supports **102** and **103**; the initially cocked flange and bent axle may now be rotated and at any instant in the rotation thereof, regardless of the angular position of the shaft, a differential will be maintained between the clamping force at the top of the flange and the clamping force at the center of the flange, creating a resultant moment of force in a direction which tends to restore the axle to a straight horizontal position with its flange perpendicular, which in this case is its position shown in solid outline in FIG. 6, or in other words to restore the axle **100** to a straight condition. Also, any tendency of the axle **100** to warp or bend in the spindle portion in any direction is opposed by the constraining effect of the flange clamping forces. Accordingly, clamping of an initially cocked flange **101** around the entire periphery thereof sets up leverage forces which are continually active to induce straightening in the flange and axle as the flange and axle are rotated; if the axle tends to bend or warp in any direction, these clamping forces at the flange oppose bending or warping of the axle, and thereby tend to maintain the axle and its flange in their desired positions.

It will be readily understood that clamping the flange by three extended lip portions, spaced at 120 degrees with respect to each other, as in FIG. 3, provides for an arrangement whereby a differential of forces resulting from clamping the flange may exist between the center and any point on an initially cocked flange regardless of the fact that the point may not be directly underneath a lip and have force directly applied thereat.

Particular reference should be made now to FIG. 7 in which an alternate embodiment of the apparatus of the instant invention is shown. In FIG. 7 the flanged end of the axle is mounted in a manner similar to that described in connection with FIGS. 2 and 3, whereas the splined end of the axle has no force applied to it along the longitudinal axis. The spline **40** is free to rotate in a bore **81** in an end piece **82**, it being understood that the end piece **82** maintains the splined end of the axle centered in its normal true position while allowing the spline to rotate within the bore **81**. As the axle expands and contracts lengthwise during the heating and cooling process the spline **40** is free to move axially within the bore **81**, maintaining the splined end centered while applying no force along the longitudinal axis of the axle. Any convenient means, not shown, may be provided for mounting the end piece **82** and moving it into engagement with the spline, or removing it while induction hardening of the spline itself.

Member **82**, FIG. 7, may if desired be mounted for rotation with the axle while maintaining complete axial freedom of movement for the spline, so that no axial force is applied to the axle.

The principles described in connection with FIG. 6 are also applicable to FIG. 7.

Particular reference should be made now to FIG. 8 in which a third embodiment of apparatus suitable for practicing the method of the invention is shown. It will be noted that the axle **109** is mounted extending in a vertical direction. The chuck body **90** rotates with a shaft **91**, the axis **107** of which is centered with the axis of rotation of the axle, and a plurality of sliding jaws or other holding means **92**, **93**, **94** and **95**, FIG. 9, are disposed at spaced intervals around the periphery of the upper surface of the chuck body and securely hold the axle flange **108** against the face or adjacent surface **96** of the chuck, in a position perpendicular to the true axis of the shaft as defined by centering piece **110** and the chuck body **90**; the holding means **92**, **93**, **94** and **95** being securely held in place, if desired, by the addition of bolt members **112**, **113**, **114** and **115** respectively, FIG. 9 or other convenient means. In FIG. 8 initial deviation of the axle from a straight condition creates a force differential between opposite points on the axle flange **108** urging it toward perpendicularity and serving as a lever to set up moments in the axle opposing the deviation. Any point "*p*" in the circular line where the flange first touches the chuck body may be a fulcrum point.

The entire length of the axle may have heating and quenching apparatus moved adjacent thereto, movement of the heating and quenching means being unrestricted. As previously stated no force, or only a very small and insignificant force, is applied along the longitudinal axis of the axle **33** or **109**, and this force is never sufficient to create moments in the axle which offer any substantial aid to bending or warping forces which may be set up in the axle during the hardening or heat-treating process, and sets up no moment or no significant moment of force in a direction to bend the axle. As previously explained, clamping forces applied to the flange **34** or **108** tend to create in the axle moments or components of forces which act to induce straightening of initially bent conditions and which oppose bending or warping force set up in the axle **33** or **109**, during the heat treatment.

Whereas the invention has been shown and described with reference to a flange which extends perpendicular to the normal longitudinal axis of the axle, it should be understood that the method is suitable for use with axles having flanges which extend at other angles.

Induction coil **43** and quenching or cooling means **44** are not shown in FIGS. 7 and 8 merely for convenience of illustration. It will be understood that these embodiments in FIGS. 7 and 8 embrace heating and cooling means.

It will be understood that motor **50** or other rotating means may be dispensed with, and omitted from, the apparatus of FIGS. 7 and 8, where rotation of the axle during treatment is not necessary.

Whereas the invention has been shown and described with particular reference to induction heating of the axle, it should be understood that flame heating could be employed if desired.

From the foregoing it should be apparent that where a bent axle which includes a deviation of its flange from a position of perpendicularly to the true axis of the axle is to be heat-treated, merely mounting the axle in the apparatus sets of forces which tend to straighten the axle. After the ends are held centered, a differential in forces is set up by the mere clamping of the flange, which differential creates moments in the axle which tend to straighten it. These desirable and helpful forces are not diminished or nullified by moments resulting from any substantial axial force applied between the ends of the axle, since any such axial force in the present invention is merely relied on to maintain the spline end of the axle on center.

In summary, by the apparatus and method of the present invention a flanged axle may be heat treated while maintaining a greater degree of integrity in position of its flange or of its flange and shaft than heretofore afforded by prior art methods and apparatus for heat treating or surface hardening flanged axles.

Whereas the invention has been shown and described with reference to some embodiments thereof which give satisfactory results, it should be understood that changes may be made and equivalents substituted without departing from the spirit and scope of the invention.

I claim as my invention:

1. A method of heat treating an axle having an elongated shaft and a flange extending outwardly of said shaft, which comprises consecutively heating and quenching said shaft, and, during such heating and quenching, applying forces to said axle including to face portions of its flange in a manner and magnitude which causes the axle flange to assume and be maintained in a prescribed angular attitude with respect to a straight axis passing through the center of said flange and of a longitudinally separated rotary-connection-adaptive portion of said shaft.

2. The heat treating method of claim **1**, wherein the

aforesaid forces include forces which are applied simultaneously on opposite faces of the axle flange.

3. A method of heat treating an axle having an elongated shaft and a flange at one end of the shaft extending in a radially outward direction therefrom, which comprises heating and quenching said shaft progressively along its length, holding opposite ends of said shaft centered on a straight common axis during such heating and quenching, and applying clamping forces to said flange in a direction parallel to said axis which results in said flange assuming and being maintained in a position perpendicular to said axis during the heating and quenching.

4. The heat treating method of claim 3, wherein the aforesaid clamping forces are applied simultaneously on opposite faces of the axle flange.

5. A method of heat treating an elongated axle having at respective longitudinally spaced-apart locations therealong a radially-extending flange and one end of the axle, heating and quenching said axle progressively along its length while being rotated about a straight axis passing centrally through said axle at such locations, and, during such heating and quenching, applying forces to radially-extending periphery-adjacent face portions of the axle flange in a direction parallel to said axis and independently of any force transmitted via any considerable length of said axle, while defining a back-up position perpendicular to said axis to which said flange is forced by such forces, and while holding said axle at the aforesaid locations centered on said axis.

6. A method of heat treating an elongated axle having a flange at one end, heating and quenching said axle progressively along its length while being rotated about a straight axis passing centrally through its opposite ends, and, during such heating and quenching, applying clamping forces simultaneously to opposite radially-extending faces of the axle flange forcing said flange to assume and be maintained in a position perpendicular to the aforesaid axis, and holding opposite ends of the axle centered on such axis during the applying of the clamping forces.

7. A method of heat treating an axle having an elongated straight shaft and a flange at one end of the shaft extending in a radially outward direction therefrom, which comprises inductively heating and quenching the outer surface of said shaft progressively along its length while rotating said axle with radial constraint about an axis passing centrally through opposite axle ends, and simultaneously forcing the axle flange to a position perpendicular to said axis by a thrust force delivered to the center of the flanged end of the axle and a reactionary back-up on a radially-extending face of the axle flange.

8. In a method of heat treating an initially-bent axle having an elongated shaft and a flange extending radially outward at one end thereof, including progressively inductively heating and quenching the outer surface of said shaft along its length while rotating the axle about an axis passing centrally through opposite axle ends, the steps of forcing the axle flange to assume and be maintained in a position perpendicular to the aforesaid axis during such heating and quenching, and holding opposite ends of the axle shaft centered on said axis during such heating, quenching, and forcing of the axle flange.

9. A method of heat treating an axle having a shaft portion joined at one end to a coaxial flange which has at least an annular face portion intended to extend in a plane substantially perpendicular to a straight axis passing centrally through opposite ends of the axle, which comprises the steps of positioning opposite ends of the axle in centered radially-constrained alignment with a fixed axis, forcing the aforesaid annular part of the axle flange toward a position perpendicular to such fixed axis by use of forces transmitted to the flange in a direction substantially parallel to the aforesaid fixed axis and independently of the shaft portion of the axle, and consecutively inductively heating and quench cooling the shaft portion of the axle progressively along its length while maintaining the aforesaid alignment of opposite axle ends and the aforesaid clamping of the axle flange.

10. Apparatus for heat treating an initially bent axle having an elongated shaft and a flange extending radially outward from a longitudinal portion of said shaft, comprising means for center mounting opposite ends of such an axle with radial constraint on a common axis, means for progressively heating and quenching the outer surface of the axle shaft along its length, a member for contact by a radially-extending face portion of the axle flange to define a desired attitude of such face portion with respect to said axis, and means for applying forces to the axle flange in a direction extending parallel to said axis to force the aforesaid face portion of the axle flange against said member with sufficient force to cause same to assume the aforesaid desired attitude during the progressive heating and quenching and while opposite ends of the axle are held centered on the aforesaid axis.

11. Apparatus for heat treating an axle having a flange and an elongated shaft, comprising mounting means for holding opposite ends of such axle centered on a common axis, means for progressively heating and cooling the shaft portion of the axle along its length, and clamping means cooperable with said mounting means for contact with opposite radially-extending faces of the axle flange to strongly urge such flange toward a desired attitude with respect to the aforesaid axis during heating and quenching.

12. Apparatus for heat treating an axle having a shaft and a flange with an annular flat face portion coaxial with and extending perpendicularly of an immediately adjacent portion of the axle shaft, comprising mounting means for rotatably holding opposite ends of the axle centered on a common axis, means for rotating the axle, heating and quenching means including an induction heating coil and quench ring for progressively heating and quenching the axle shaft along its length while being rotated about said axis, a rotatable member having flat surface portions distributed around said axis and lying in a common plane perpendicular to such axis, and rotatable force applying means adjacent to said rotatable member and movable along said axis to force the flat face portion of the axle flange into contact with all of said flat surface portions while opposite axle ends are being held centered on a common axis and during heating and quenching.

13. Apparatus for heat treating an axle having an annular flange with a face portion intended to extend in a plane perpendicular to a straight axis passing centrally through the axle at longitudinally spaced-apart locations thereof, mounting means for mounting such axle for rotation with radial constraint coaxially about a fixed axis at axially-separated locations corresponding to the aforesaid locations on the axle, a member rotatable about said fixed axis having a surface extending in a plane perpendicular thereto for abutting contact with the face portion of the axle flange, rotating means for effecting rotation of the axle about the fixed axis, heating and quenching means for consecutively heating and quenching the axle along its length while mounted in said mounting means and being rotated, and force-applying means adjacent to said member and relatively movable with respect thereto in the direction of extension of said fixed axis for causing the aforesaid face portion of the axle flange to be forced into contact with the aforesaid surface of such member at points distributed entirely around such face portion while the axle is being rotated, heated and quenched, and constrained by the mounting means.

14. Apparatus as set forth in claim 13, further characterized in that at least one of the spaced-apart locations on the axle is at one end thereof, and the portion of the mounting means respective to this location has a bore therein coaxial with the said fixed axis which rotatably holds such end of the axle centrally aligned on the fixed axis.

15. Apparatus as set forth in claim 13, further characterized in the axle flange is located at one end of the

axle at one of the spaced-apart locations thereof, and the force applying means as well as the respective portion of the mounting means is in the form of a tapered center pin aligned with and movable along the aforesaid fixed axis.

16. Apparatus as set forth in claim **13**, further characterized in that the force applying means and the aforesaid member each are constructed and arranged for contact with the axle flange on opposite faces thereof, respectively, adjacent to its outer periphery.

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