Mechanical component (10) having a hole (12) extending therethrough and having a minimum thickness (T) of 7 mm, measured from an interior surface (12a, 12b) constituting the outer perimeter of the hole (12) radially outwards to an outer surface of said mechanical component (10). The maximum transverse dimension (d) of said hole (12) is 31.75 mm or less and that at least one part (22) of interior surface (12a, 12b) material of the mechanical component (10) constituting the outer perimeter of said hole (12) comprises a martensitic microstructure produced by induction hardening using an electromagnetic induction coil (14) positioned inside said hole (12) followed by immediate quenching using a quenching device (16) that is positioned inside said hole (12) when the electromagnetic induction coil (14) has been removed from said hole (12) or while the electromagnetic induction coil (14) is being removed from said hole (12).
MECHANICAL COMPONENT AND METHOD OF SURFACE HARDENING

CROSS-REFERENCE TO RELATED APPLICATION

This application is a National Stage application claiming the benefit of International Application Number PCT/SE2011/000093 filed on 27 May 2011, which claims the benefit of SE Application 1000720-1 filed on 2 Jul. 2010.

TECHNICAL FIELD

The present invention concerns a mechanical component having a hole extending therethrough, such as a pierced roller. The present invention also concerns a method for surface hardening at least one part of an interior surface of such a mechanical component.

BACKGROUND OF THE INVENTION

Induction hardening is a heat treatment in which a metal component is heated to the ferrite/austenite transformation temperature or higher by induction heating and then quenched. The quenched metal undergoes a martensitic transformation, increasing the hardness and brittleness of the surface of a metal component. Induction hardening may be used to selectively harden areas of a mechanical component without affecting the properties of the component as a whole.

Carburizing is a heat treatment process in which iron or steel is heated in the presence of another material that liberates carbon as it decomposes. The outer surface or case will have higher carbon content than the original material. When the iron or steel is cooled rapidly by quenching, the higher carbon content on the outer surface becomes hard, while the core remains soft (i.e. ductile) and tough.

SUMMARY OF THE INVENTION

An object of the invention is to provide an improved non-through hardened mechanical component having a hole of uniform or non-uniform cross section extending therethrough, i.e. extending at least part of the way through the mechanical component, whereby the maximum transverse dimension of the hole is 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 or 5.0 mm, and whereby the minimum thickness of the mechanical component is 5 mm, measured from an interior surface constituting the outer perimeter of the hole radially outwards to an outer surface of the mechanical component.

This object is achieved by a mechanical component in which at least one part of interior surface material of the mechanical component constituting the outer perimeter of the hole comprises a martensitic microstructure produced by induction hardening using an electromagnetic induction coil positioned inside the hole followed by immediate quenching using a quenching device that is positioned inside the hole when the electromagnetic induction coil has been removed from the hole or while the electromagnetic induction coil is being removed from said hole. The at least one part of the interior surface material may have a hardness within the range of 55-75 HRC on the Rockwell scale at the interior surface, preferably 58-63 HRC and the material of increased hardness may extend to a depth of about 0.5-6 mm below the interior surface, preferably 1-4 mm below the interior surface.

At least one part of the interior surface of such a non-through hardened mechanical component will exhibit increased surface hardness, increased wear resistance and/or increased fatigue and tensile strength. Furthermore, the induction hardening heat treatment used to produce such a mechanical component is more energy efficient and cost effective than a carburizing heat treatment and it has a shorter cycling time and provides better distortion control than a carburizing heat treatment. Furthermore, properties, such as the hardness, microstructure and residual stress, of the at least one part of the interior surface may be tailored as desired for a particular application.

According to an embodiment of the invention the at least one part of the interior surface extends to a depth of 0.2, 0.3, 0.4, 0.5, 0.75 or 1.0, below said interior surface.

According to an embodiment of the invention the at least one part of the interior surface extends to a depth of 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5 or 6.0 mm below said interior surface.
According to an embodiment of the invention the maximum transverse dimension of the hole is 5-31.75 mm, preferably 10-30 mm.

According to another embodiment of the invention the minimum thickness of the mechanical component measured from the interior surface radially outwards towards the outer surface of the mechanical component is 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm, 70 mm, 80 mm, 90 mm, 100 mm or more.

According to a further embodiment of the invention at least one part of the interior surface constituting the outer perimeter of the hole comprises a thread.

According to an embodiment of the invention the mechanical component constitutes a rotationally symmetrical mechanical component.

According to another embodiment of the invention the mechanical component constitutes a rolling element or roller, or a component for an application in which is subjected to alternating Hertzian stresses, such as rolling contact or combined rolling and sliding, such as a slewing bearing or a raceway for a bearing. The mechanical component may for example be used in automotive and machine applications which require high wear resistance and/or increased fatigue and tensile strength.

According to a further embodiment of the invention the mechanical component comprises, or consists of a carbon or alloy steel with an equivalent carbon content of 0.40 to 1.10%, preferably a high carbon chromium steel. For example the mechanical component comprises/consists of 50CrMo4 steel having a composition in weight % of 0.50 C, 0.25 Si, 0.70 Mn, 1.10 Cr, 0.20 P and 100Cr6 steel or SAE 1070.

The present invention also concerns a method for surface hardening at least one part of an interior surface of a mechanical component having a hole maximum transverse dimension of 31.75 mm or less extending therethrough, whereby the mechanical component has a minimum thickness of 7 mm, measured from an interior surface constituting the outer perimeter of the hole radially outwards to an outer surface of the mechanical component. The method comprises the steps of inserting an electromagnetic induction coil within the hole, heating the at least one part of the interior surface to the ferrite/austenite transformation temperature or higher by induction heating, removing the electromagnetic induction coil from the hole and simultaneously or subsequently inserting a quenching device within the hole to immediately quench said at least one part of the interior surface.

According to an embodiment of the invention the method comprises the step of inserting the electromagnetic induction coil into one end of the hole, removing the electromagnetic induction coil from the hole via the same end of the hole and inserting the quenching device from the other end of the hole. This enables a quick start of the quenching, and especially quick start if the quenching device is being inserted while the induction coil is being removed.

The method according to the present invention is based on the finding that such a method ensures that the interior surface of a mechanical component is heated and quenched sufficiently quickly to obtain the desired microstructure in the interior surface.

According to an embodiment of the invention the method comprises the step of also providing at least one external quenching device on the outside of the mechanical component to immediately quench the at least one part of the interior surface. This is especially advantageous when using mechanical components with thin walls, where heat from the induction coil might also affect a part of the mechanical component’s microstructure that should not be affected, e.g. an initial microstructure or an already hardened microstructure on an external or internal surface. The external quenching device may then be used to protect such a part’s microstructure from the heat.

It should be noted that the expression “an induction coil” as used throughout this document with reference to the mechanical component and method according to the present invention is intended to mean one or more induction coils. A plurality of induction coils operating in the same or a different manner, for example at the same or different frequencies, may for example be used to simultaneously or consecutively heat a plurality of parts of the interior surface (and/or the outer surface) of a mechanical component, or one or more parts of a plurality of mechanical components.

According to an embodiment of the invention the method comprises the step of heating the at least one part of the interior surface to a depth of 0.2, 0.3, 0.4, 0.5, 0.75 or 1.0 mm below said interior surface.

According to an embodiment of the invention the at least one part of the interior surface extends to a depth of 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5 or 6.0 mm below said interior surface.

According to another embodiment of the method the maximum transverse dimension of the hole is 5-31.75 mm, preferably 10-30 mm.

According to a further embodiment of the method the minimum thickness of the mechanical component measured from the interior surface radially outwards towards the outer surface of the mechanical component is 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm, 70 mm, 80 mm, 90 mm, 100 mm or more.

According to an embodiment of the method at least one part of the interior surface constituting the outer perimeter of the hole comprises a thread.

According to an embodiment of the method the mechanical component constitutes a rotationally symmetrical mechanical component.

According to another embodiment of the invention the mechanical component constitutes a roller or a component for an application in which is subjected to alternating Hertzian stresses, such as rolling contact or combined rolling and sliding.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be further explained by means of non-limiting examples with reference to the schematic appended figures where:

FIGS. 1 & 2 show the steps of a method according to an embodiment of the present invention, and

FIG. 3 shows a cross section of a mechanical component according to an embodiment of the invention.

It should be noted that the drawings have not been drawn to scale and that the dimensions of certain features have been exaggerated for the sake of clarity.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 schematically shows a thick-walled rotationally symmetrical mechanical component 10 manufactured from bearing steel, namely a cylindrical roller, in cross section. The roller 10 is, for example, made of 50CrMo4 steel
and comprises a hole 12 having a diameter d and a uniform circular cross section which extends all the way through the centre of the component in the longitudinal direction thereof. The roller 10 has a minimum thickness T measured from an interior surface 12a constituting the outer perimeter of the hole 12 radially outwards to an outer surface 10a of the roller 10 (or from 12b to 10b). The minimum thickness T is 7 mm, 10 mm, 20 mm, 30 mm or more. The diameter d of said hole 12 is 31.75 mm or less. The hole 12 may alternatively be conical for example and thus have a non-uniform cross sectional size, whereupon its maximum diameter is 31.75 mm or less. Alternatively or additionally, the hole 12 may be arranged to have a non-uniform cross sectional shape.

[0036] In order to harden at least one part of the interior surface 12a, 12b of the roller 10, i.e. the at least one part of the surface constituting the outer perimeter of the hole 12 an electromagnetic induction coil 14 is inserted inside the hole 12 at the left hand side end of the hole. A source of high frequency electricity (about 1 kHz to 400 kHz) is used to drive a large alternating current through the induction coil 14. The relationship between operating frequency and current penetration depth and therefore hardness depth is inversely proportional, i.e. the lower the frequency the greater the hardness depth.

[0037] The passage of current through the induction coil 14 generates a very intense and rapidly changing magnetic field, and the part of the interior surface 12a, 12b to be heated is placed within this intense alternating magnetic field. Eddy currents are generated within that part of the interior surface 12a, 12b and resistance leads to Joule heating of the metal in that part of the interior surface 12a, 12b. The interior surface 12a, 12b of the roller 10 is heated to the ferrite/austenite transformation temperature or higher by induction heating and preferably maintained at that temperature for 10-40 seconds.

[0038] In order to select the correct power supply it is first necessary to calculate the surface area of the roller to be heated. Once this has been established empirical calculations, experience and/or a technique such as finite element analysis may be used to calculate the required power density, heating time and generator operating frequency.

[0039] In the illustrated embodiment the induction coil 14 is then removed via left-hand side end of the hole 12 and a quenching device 16, such as a quench spray or ring, is inserted via the right-hand side hole 12 to immediately quench the at least one part of the interior surface 12a, 12b that has been heat treated. The at least one part of the interior surface 12a, 12b may for example be quenched to room temperature (20-25°C.) or to 0°C. or less. The quenching device 16 is arranged to provide a water-, oil- or polymer-based quench to the heated interior surface layer 12a, 12b whereupon a martensitic structure which is harder than the base metal of the roller 10 is formed. The microstructure of the remainder of the roller 10 remains essentially unaffected by the heat treatment and its physical properties will be those of the bar from which it was machined. It should be noted that the 5 quenching device 14 may be inserted via the same (left-hand side) end of the hole 12 as the induction coil 14 after the induction coil 14 has been removed from the hole 12.

[0040] As an example, a 60-200 kW power supply, a frequency of 20-60 kHz, preferably 10-30 kHz or 15-20 kHz a total heating time of 10-40 seconds and a quenching rate and time of 10 2001/min and quenching time of 40-70s respectively may be used to obtain a mechanical component according to the present invention.

[0041] FIG. 2 shows the position of the quenching device 16 while quenching is taking place. FIG. 2 also shows that one or more additional external quenching devices 20 may also be positioned on the outside of the roller during the quenching step.

[0042] It should be noted that at least one part of the outside surface 10a, 10b of the roller 10 may be subjected to a surface hardening heat treatment, such as induction hardening, flame hardening or any other conventional heat treatment.

[0043] Furthermore, even though the roller 10 in the illustrated embodiment has been shown in a horizontal position with the induction coil 14 and quenching device 16 being inserted horizontally, it should be noted that the roller 10 may be oriented in any position. An induction coil 14 and quenching device 16 may for example be inserted vertically into a roller 10 from the same or different ends of the hole 12. An induction coil 14 may for example be inserted into a roller 10 by lowering it vertically into the roller’s hole 12 and a quenching device may be inserted into a roller’s hole 12 by raising it vertically as the induction coil 14 is withdrawn by raising it vertically.

[0044] FIG. 3 shows a cross section of the roller 10 after the heat treatment. Part 22 of the interior surface material 12a, 12b of the roller 10 constituting the outer perimeter of the hole 12 extending therethrough comprises a martensitic microstructure produced by induction hardening using the electromagnetic induction coil 14 positioned inside the hole 12 followed by immediate quenching using a quenching device 16 positioned inside the hole 12 and optionally one or more external quenching devices 20.

[0045] The method according to the present invention results in the formation of a transition zone visible in both hardness and in microstructure. The heat treated part 22 of the interior surface material 12a, 12b may namely have a hardness within the range of 55-75 HRC on the Rockwell scale at the interior surface 12a, 12b, preferably 58-63 HRC. The volume of material of increased hardness 22 may for example extend to a depth of 1 to 2 mm below the interior surface 12a, 12b measured radially outwards from the interior surface 12a, 12b of the roller 10 to the outer surface of the roller 10a, 10b respectively. Such a roller 10 may be used for any application in which a part of the interior surface 12a, 12b is subjected to increased wear, fatigue or tensile stress. Alternatively, the entire interior surface 12a, 12b may be subjected to the method according to the present invention, depending on the application for which the roller 10 is to be used.

[0046] The interior surface 12a, 12b of the roller 10 may for example comprise a thread (not shown) arranged to mate with a corresponding thread of another component.

[0047] Further modifications of the invention within the scope of the claims would be apparent to a skilled person.

1. A mechanical component comprising a cylindrically shaped body having a hole extending therethrough and having a minimum thickness of 7 mm, measured from an interior surface constituting the outer perimeter of the hole radially outwards to an outer surface of said cylindrically shaped body, of said hole is having a maximum transverse dimension of 31.75 mm or less, and
at least one part of interior surface material of the cylindrically shaped body constituting the outer perimeter of said hole comprises a martensitic microstructure produced by induction hardening using an electromagnetic induction coil positioned inside said hole followed by immediate quenching using a quenching device that is positioned inside said hole when one of:

a) the electromagnetic induction coil has been removed from said hole, or
b) while the electromagnetic induction coil is being removed from said hole.

2. The mechanical component according to claim 1, wherein said at least one part of the interior surface extends to a depth that is of one of 0.2, 0.3, 0.4, 0.5, 0.75, 1.0 mm below said interior surface.

3. The mechanical component according to claim 1, wherein the maximum transverse dimension of the hole is between 5 and 31.75 mm.

4. The mechanical component according to claim 1 wherein the minimum thickness of the mechanical component measured from said interior surface radially outwards towards the outer surface of said mechanical component is one of 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm, 70 mm, 80 mm, 90 mm, 100 mm, and greater than 100 mm.

5. The mechanical component according to claim 1, wherein at least one part of said interior surface constituting the outer perimeter of the hole comprises a thread.

6. The mechanical component according to claim 1, said mechanical component is formed into a rotationally symmetrical mechanical component.

7. The mechanical component according to claim 1, said mechanical component is formed into one of a roller and a component for an application in which is subjected to alternating Hertzian stresses, including at least one of a rolling contact and a sliding contact.

8. A method for surface hardening at least one part of an interior surface of a mechanical component having a hole maximum transverse dimension of 31.75 mm or less extending therethrough, whereby the mechanical component has a minimum thickness of 7 mm, measured from an interior surface constituting the outer perimeter of the hole radially outwards to an outer surface of said mechanical component, the method comprises the steps of:

inserting an electromagnetic induction coil within said hole,
heating said at least one part of the interior surface to at least the ferrite/austenite transformation temperature by induction heating,
removing said electromagnetic induction coil from said hole and
one of simultaneously and subsequently inserting a quenching device within said hole to immediately quench said at least one part of the interior surface.

9. The method according to claim 8, further comprising steps of:

removing said electromagnetic induction coil from said hole via the same end of the said hole, and
inserting said quenching device from the other end of said hole.

10. The method according to claim 8, further comprising a step of also providing at least one external quenching device on the outside of said mechanical component to immediately quench said at least one part of the interior surface.

11. The method according to claim 8, wherein the step of heating said at least one part of the interior surface is further limited to heating said at least one part of said interior surface to a depth of one of 0.2, 0.3, 0.4, 0.5, 0.75, and 1.0 mm below said interior surface.

12. The method according to claim 8, wherein the maximum transverse dimension of the hole is between 5 and 31.75 mm.

13. The method according to claim 8, wherein the minimum thickness of the mechanical component measured from said interior surface radially outwards towards the outer surface of said mechanical component is one of 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm, 70 mm, 80 mm, 90 mm, 100 mm, and greater than 100 mm.

14. The method according to claim 8, wherein at least one part of said interior surface constituting the outer perimeter of the hole comprises a thread.

15. The method according to claim 8, further comprising a step of forming said mechanical component constitutes into a rotationally symmetrical mechanical component.

16. The method according to claim 8, further comprising a step of forming said mechanical component into one of a roller and a component for an application in which is subjected to alternating Hertzian stresses, including at least one of a rolling contact and a sliding contact.

17. The mechanical component according to claim 1, wherein the maximum transverse dimension of the hole is between 10 and 30 mm.

18. The method according to claim 8, wherein the maximum transverse dimension of the hole is between 10 and 30 mm.