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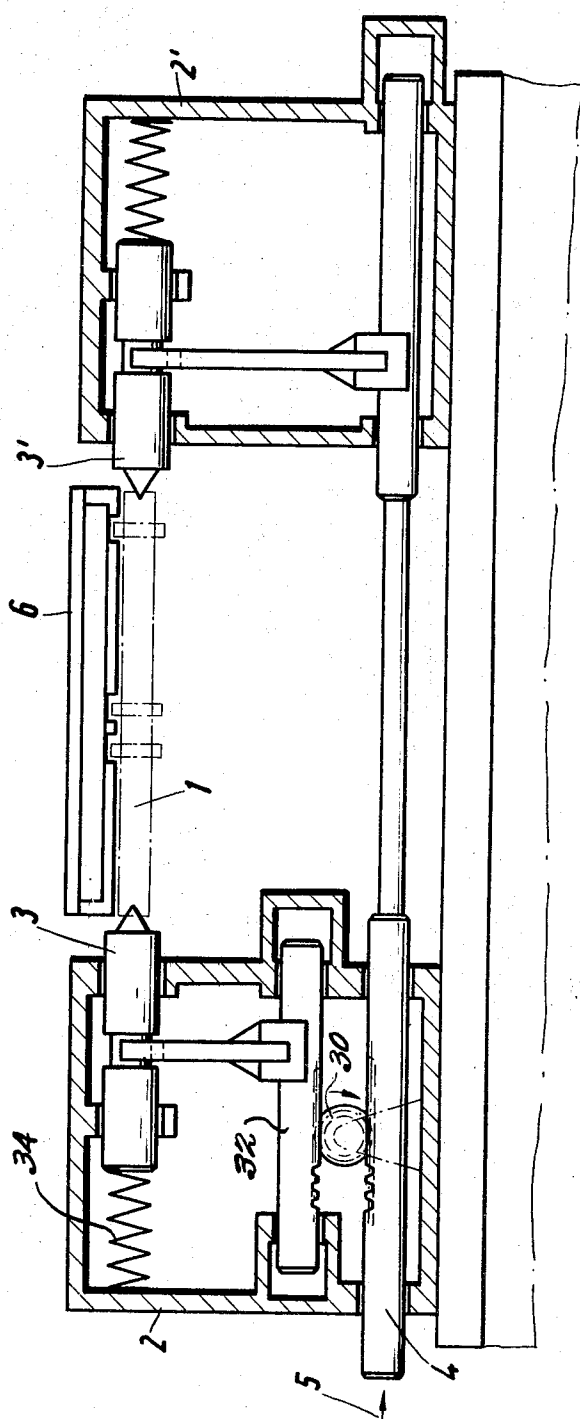
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PROCESS FOR THE IMPROVEMENT OF THE DEVELOPMENT OF THE
TEXTURE OF INDUCTIVE SURFACE-HARDENED STEEL PARTS

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4 Sheets-Sheet 1

Fig. 1



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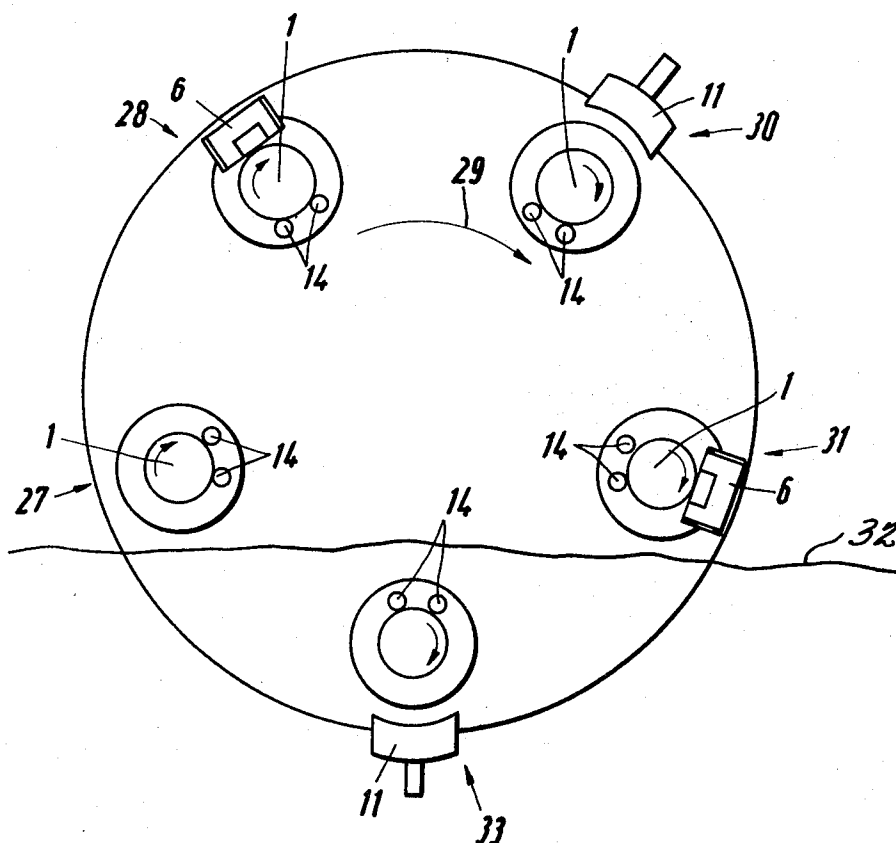
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4 Sheets-Sheet 2

Fig. 2



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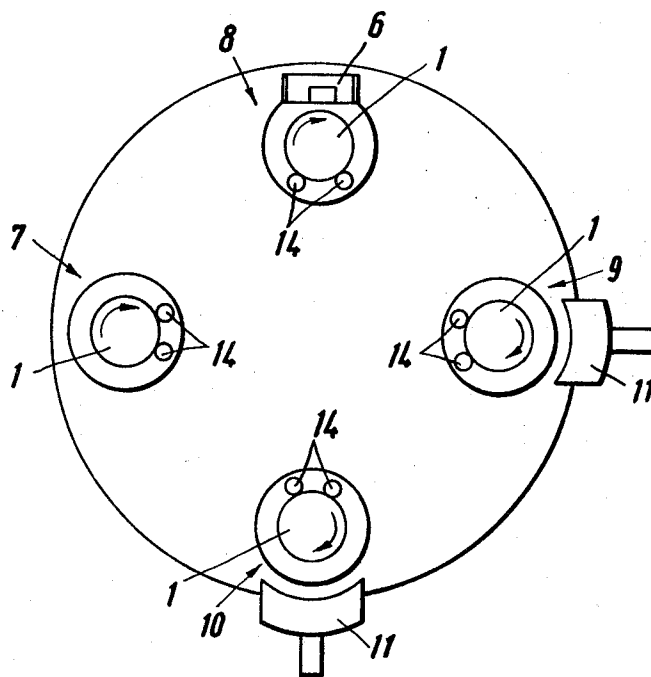
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4 Sheets-Sheet 3

Fig. 3



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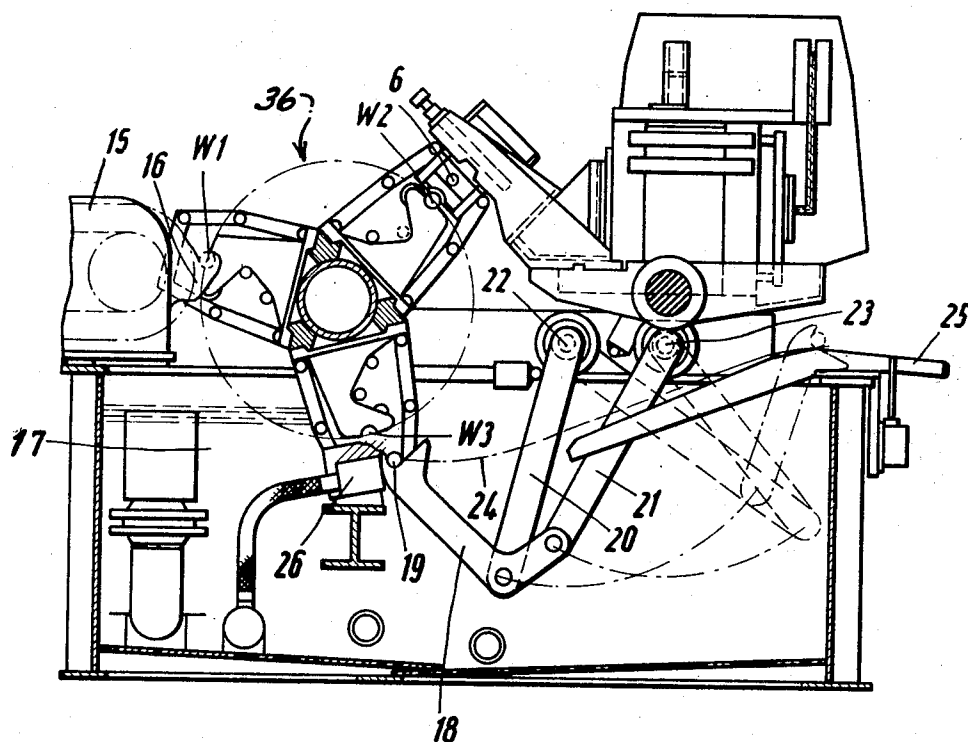
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Fig. 4



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3,682,721

PROCESS FOR THE IMPROVEMENT OF THE DEVELOPMENT OF THE TEXTURE OF INDUCTIVE SURFACE-HARDENED STEEL PARTS

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6 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for inductively surface hardening a steel workpiece wherein the workpiece is first heated to a temperature above the highest critical temperature AC_3 , cooled to a temperature below the lowest critical temperature AC_1 , so that the structure of the steel consists of pearlite or bainite, inductively reheated to a temperature above AC_3 and quenched. Preferably the workpieces are elongated and are continuously rotated during heating and cooling. The apparatus disclosed includes a machine with a number of working stations for heating and cooling the workpiece and a carrier spider for moving the workpieces from station to station.

The invention relates to an improved method of and apparatus for inductively surface hardening steel parts to obtain an improved grain structure.

When steel parts are surface hardened by heating with currents induced in the workpiece and then quenched, the grain structure of the metal in the hardened zone may not be uniform if the initial structure prior to hardening was not uniform. Such non-uniformities may occur when the steel parts which are to be surface hardened have been previously only partly raised to a proper forging temperature before forging and then cooled without sufficient control exercised.

It is also possible for parts that have been completely heated in forging to exhibit a nonuniform initial grain structure if they have not been thereafter uniformly cooled, particularly if the cooling rate is not uniform. This formation of interphase structures and/or pearlite does not necessarily have significantly adverse consequences in a subsequent surface hardening treatment. However, if a ferritic structure has formed to any appreciable extent, then the relatively short time available for austenite formation during inductive heating does not always assure a uniform accumulation of austenite for the subsequent hardening. The result is that, when the part has a heterogeneous austenite phase with a relatively large proportion of bainite, the hardness achieved in these regions is considerably less than the desired value thereby adversely affecting the wear resistance and/or fatigue strength of the treated steel part. These irregularities have a particularly undesirable effect when the parts are likely to experience fatigue stressing. For instance, in long shafts such as side shafts, rear axle shafts, propeller shafts, as used in motor cars, torsional fatigue fracture regularly occurs in those areas where the strength is impaired because of an insufficiently developed structure.

In order to eliminate these defects, the present invention provides a novel method of inductively surface hardening parts made of heat-treated steel wherein the development of the grain structure is improved. This is accomplished by first inductively heating the zone of the

workpiece to be hardened by overall surface heating to a temperature above the AC_3 temperature, which is the highest critical temperature, and then cooling it to a temperature below the AC_1 temperature, which is the lowest critical temperature, in such a way that the structure of the steel, after having cooled, has a pearlitic or a bainite. Subsequently the zone is inductively reheated above the AC_3 temperature and quenched-hardened from this temperature in conventional manner, for example in water, oil or an emulsion.

A particular advantage of the method of this invention is that cooling from the first heating which begins at a temperature above the AC_3 temperature is accelerated because the cold core of the workpiece draws the heat from the heated zones, external cooling being simultaneously carried out, for example, in a current of air or a liquid mist in air. After the subsequent reheating of the zones that are to be hardened to temperatures above the AC_3 point, the core will have a reduced strength due to its raised temperature. Final quenching first causes martensite to form in the surface layers, and the reduced strength of the core offers a lower resistance to the compressive stresses in the transition zones due to the formation of the martensite with the result that the residual tensile stresses in these zones are less than would occur if the resistance of the core had not been reduced since the forces required are distributed over wider areas of the core.

When the method of the invention is applied to elongate workpieces which are already distorted prior to being thermally treated or which tend to distort during hardening, then a further feature of this invention includes straightening the workpiece during the repeated heating, cooling and quenching steps. During thermal treatment the workpieces may rotate and a force acting radially to the workpiece axis can be applied thereto by rolls to accomplish the straightening. Because of the raised temperature of the core and the resultant reduced strength of the workpiece core, the straightening process is much more successful than when the core is completely cold, and the generated straightening strains are less than in a cold straightened part.

The method of the invention is not restricted to the use of any particular apparatus. However a further feature of the invention provides apparatus for carrying out the method, namely, an inductive hardening machine comprising at least five working stations and fitted with a carrier spider having at least five arms fitted with work gripping spindles. For performing the heat treatment the machine includes a loading and unloading station, two heating stations and two cooling stations.

The method of the invention may be alternatively carried out on two separate machines, each machine being provided with three working stations and with a spider comprising at least three arms and fitted with three pairs of work gripping spindles. The two machines may be positioned in any convenient manner, e.g. side-by-side or in tandem. The machine for performing the heat treatment includes a loading and unloading station, a heating station and two cooling stations and the hardening machine includes a loading station, a heating station and a quenching and unloading station. The invention is hereinafter further described and illustrated in the accompanying drawings, of which:

FIG. 1 is a longitudinal section of part of a carrier spider for use in apparatus according to the invention;

FIG. 2 is a schematic side elevation of a five-station machine according to the invention;

FIG. 3 is a schematic side elevation of a carrier spider of a preheating machine for use according to the invention; and

3

FIG. 4 is a part sectional view of a hardening machine for use according to the invention.

Reference is now made to FIG. 1 wherein the manner in which the workpiece 1 is mounted in a carrier spider which conveys it from one treating station to the next is illustrated. In FIG. 1 only one pair of arms 2, 2' of the spider is visible, but it will of course be understood that each spider has a pair of arms for each working station. The workpiece is mounted between the centers of a pair of spindles 3, 3', so that, when force is applied to cause rod 4 to move in the direction indicated by arrow 5, the fixed rotary member 30 exerts a force of the opposite direction on rod 32, which then moves in a direction opposite to rod 4, carrying with it spindle 3 so that the two spindles separate and the workpiece is released. A spring 34 urges spindle 3 in a direction opposite to arrow 5. The pair of arms 2, 2' of the carrier spider is represented in FIG. 1 in a position in which the workpiece is at a heating station and the workpiece 1 is shown located beneath an inductor 6 which is supplied with alternation current from a suitable source.

FIG. 2 illustrates one embodiment of the invention. In this figure, it is assumed that the loading and unloading station is station 27, at which point the workpieces to be treated are transferred to the spider and the treated workpieces are removed. After a workpiece is loaded onto the spider at station 27 the spiders rotate in the direction indicated by arrow 29 to heating station 28 at which the first heat treatment is performed. After being heated to a temperature above the AC_3 temperature by a conventional inductor 6 at station 28, the workpiece is next rotated to a cooling station 30 where it is cooled by a current of air or of a mixture of liquid and gas discharged by sprayer head 11. A further step rotation takes the workpiece to a second heating station 31 where it is again inductively heated to a temperature above the AC_3 temperature, by an inductor 6, this time for the purpose of being surface-hardened. After the workpiece has been thus heated, the next indexing step of the spider lowers it into a quench bath, the level of the quench bath being approximately indicated at 32. The workpiece 1 then moves to quenching station 33 which may contain a supplementary sprayer head 11. After quenching, the workpiece may be removed from the quench bath at the station 33 by means hereinafter described or the workpiece may be rotated to and removed at loading station 27, after a further indexing step of the spider. For the entire length of time the workpiece is in the spider, it is preferably maintained in continuous rotation about its axis by any suitable means. Moreover, each arm of the carrier spider is equipped with at least one pair of straightening rolls 14 which apply to the workpiece during the heat treatment and the hardening process a mechanical straightening force acting radially to the workpiece axis.

The invention may also be carried out in separate preheating and hardening machines. Details of one suitable preheating machine are illustrated in FIG. 3, in which spider workpieces that are to be preheated are first loaded onto the spider at station 7. The workpieces are then rotated stepwise, moving first to a heating station 8 where the workpiece is heated by inductor 6 above the temperature AC_3 next indexing step of the spider conveys the workpiece to a first cooling station 9 where it is exposed to air or a mixture of liquid and gas from a sprayer head 11. If the time provided by the indexing cycle at station 11 is not sufficient for cooling, the cooling process may be completed at another station 10 where another sprayer head 11 is provided to cool the workpiece. From station 10 the workpiece finally returns to station 7 where it is unloaded and conveyed by any suitable means to a hardening machine such as shown in FIG. 4. For moving the workpieces to and from the spider, conventional conveyors such as conveyor chains and the like, may be

4

employed. Preferably the workpieces are kept continuously in rotation about their axes, as indicated by the arrows, for the whole of the time they are mounted in the spider. Moreover, each arm of the spider is equipped with at least one pair of straightening rolls 14 which during the heat treatment and also during the hardening of the workpieces apply to the workpieces a mechanical straightening force radial to the workpiece axis.

The inductive hardening apparatus shown in FIG. 4 contains as its principal component a carrier spider 36 provided with three workholder devices such as shown in FIG. 1. The workpiece, having been conveyed on a conveyor chain 15 to a transferring point 16, is mounted between spindles as in the FIG. 1 in the position marked W_1 . When the spider has been rotated through an indexing step, which in the illustrated example corresponds to 120° , the workpiece reaches a position W_2 in which, in FIG. 4, it is exactly below an inductor 6. The workpiece is heated to hardening temperature in the inductor 6 and subsequently the spider is again indexed through a similar angle so as to immerse the workpiece in a quench bath contained in a vessel 17. Having been quenched, the workpiece in position W_3 is released by the spider and transferred to further conveyor means which removes it from the quench bath.

This further conveyor means in FIG. 4 consists of a cranked lever 18 which is formed at one end with a fork 19 for engaging the workpiece. After having been quenched in position W_3 , the workpiece is released by its holders and the forked end 19 of the cranked lever 18 is designed so as to be located below the workholders when the release takes place. The cranked lever 18 is articulatedly attached to the ends of the two swing arms 20 and 21 which are each attached at their other ends to rotatable shafts 22 and 23 respectively. The swing arm 20 is articulatedly attached to the cranked lever at the vertex angle thereof, whereas the other swing arm 21 is articulated to the end of the cranked lever 18 remote from the fork 19. One of the two shafts, for instance the shaft 22, is connected to drive means which are started as soon as a workpiece has been deposited in the fork 19 of the cranked lever 18 and which rotate the shaft 22 and thereby deflect the swing arms 20 and 21 through an angle of about 60° into the positions shown in dotted lines. The workpiece resting in the fork 12 is thus conveyed along a substantially linear path 24 marked by a dot-dash line. That path arches towards its end causing the workpiece to slide out of the fork and to drop onto a slightly inclined chute 25. To prevent the workpiece from prematurely dropping out of the work due to a malfunction of the conveyor mechanism the chute 25 rearwardly extends into the quenching vessel. Since the crutch of the fork 19 moves very closely above the extended chute the workpiece cannot drop back into the quench.

After dropping the workpiece, the fork 19 returns to its illustrated receiving position below the workholder and when it reaches this position a limit switch (not shown) preferably deactivates the conveyor means. The driving speed of the conveyor means is chosen so that the time required for a to and fro motion of the fork 19 is less than the time that elapses between indexing motions of the spider to ensure that the fork 19 will always be in position at W_3 below the workholder devices when the next workpiece is released by the spider. For assisting the quenching effect and for agitating the quench, a sprayer head 26 is additionally provided at the quenching station.

Many changes and modifications of the above embodiments of the invention can be made without departing from the scope of the invention which is intended to be limited only by the scope of the appended claims.

What is claimed is:

1. A method of inductively surface hardening at least

5

a portion of the surface of a steel workpiece to obtain an improved grain structure comprising the steps of:

inductively heating said overall surface portion of the workpiece to be hardened to a temperature above the AC_3 temperature so that the structure of the steel after cooling consists of pearlite or bainite structure,

cooling said surface portion to obtain said pearlite or bainite structure,

inductively reheating said cooled portion to a temperature above the AC_3 temperature,

quenching the reheated portion to harden it and straightening said workpiece during said heating, cooling, reheating and quenching steps.

2. A method as in claim 1 including the step of continuously rotating said workpiece during said steps of heating, cooling, reheating and quenching.

3. A method as in claim 1 wherein said workpiece is cooled, during said cooling step, to a temperature below the AC_1 temperature.

4. A method as in claim 1 wherein said cooling step includes the step of applying a fluid stream to said workpiece.

5. A method as in claim 1 wherein said step of straightening includes the step of applying at least a single straightening roll to said workpiece so that said roll rides on the surface of said workpiece so as to impart thereto a force acting radially to the axis of said workpiece.

6

6. A method of inductively surface hardening overall at least an elongated portion of a steel workpiece to obtain an improved grain structure comprising the steps of:

inductively heating the overall surface of said portion above the AC_3 temperature so that the structure of the steel after cooling consists of a pearlite or bainite structure,

cooling said portion below the AC_1 temperature to obtain said structure,

inductively reheating said portion to a temperature above the AC_3 temperature, quenching the reheated portion to harden it,

continuously rotating said workpiece during said steps of heating, cooling, reheating and quenching, and straightening said workpiece during said steps of heating, cooling, reheating and quenching.

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