United States Patent

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[54] **METHOD AND APPARATUS FOR HOT STRAIGHTENING ELONGATED METAL WORKPIECES**
13 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **72/56,** 72/69, 72/342
[51] **Int. Cl.** **B21d 26/14**
[50] **Field of Search** 72/56, 706, 69, 111, 342; 219/7.5, 10.41, 10.43; 148/130, 131, 150, 154

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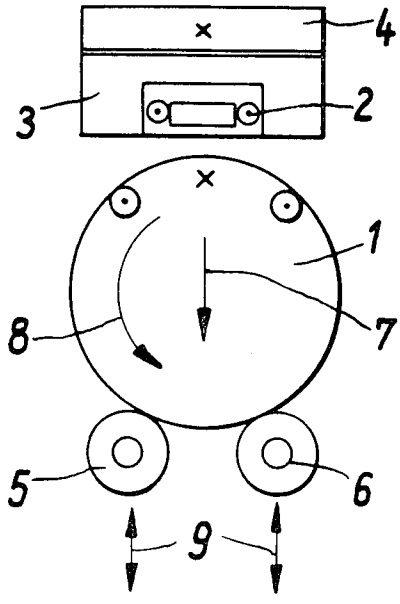
ABSTRACT: A method of straightening bent metal workpieces by nonmechanical means, namely by the use of magnetic flux generated by inductive heating moving the heated workpiece against stop members whereby straightening is achieved.

In a preferred form of the invention the workpiece is quench hardened as well as straightened.

The invention may be applied either to ferromagnetic or nonferromagnetic workpieces.



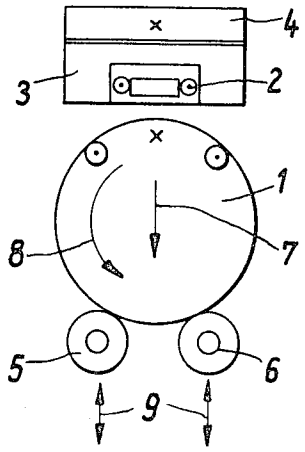


Fig. 1

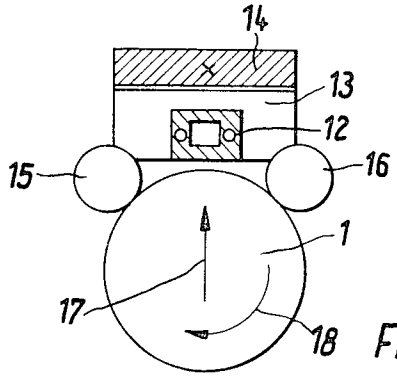


Fig. 2

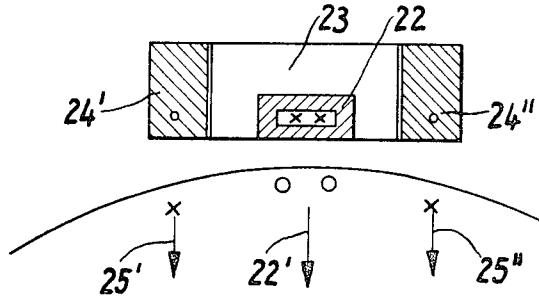


Fig. 3

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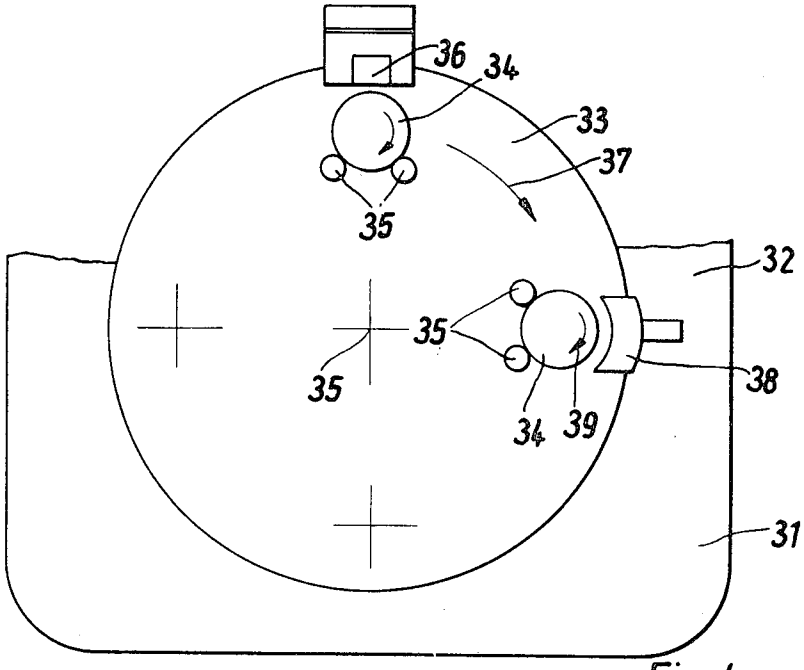

Fig. 4

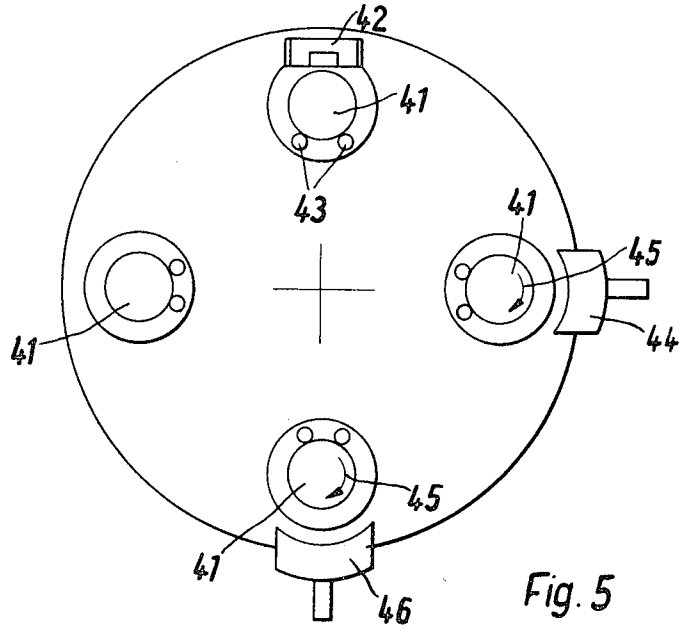

Fig. 5

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METHOD AND APPARATUS FOR HOT STRAIGHTENING ELONGATED METAL WORKPIECES

This is a division of application Ser. No. 676,753, filed Oct. 20, 1967, now abandoned.

This invention relates to the hot straightening of metal workpiece which in course of production have become bent or distorted, for instance during pressing, forging, hardening or other operations.

A known method employed for straightening elongated workpieces consists in first heating the workpiece and then straightening them while they are still hot in a press, a rolling mill or roller-straightening machine. The purpose of heating the workpieces is to reduce their strength during the straightening process, and to avoid the formation of cracks, fractures and like imperfections in the workpieces.

Such conventional straightening methods require the application of a mechanical force which corrects the distortion, but often has undesirable effects. Thus a straightening process of the described kind changes the state of internal stress in the workpiece, the straightening process introducing fresh stresses into the workpiece which often reduces the reverse bending strength and possibly also the torsional strength of the workpiece. Such reductions in strength are particularly undesirable when the workpieces are to be used for purposes in which they will be subjected to considerable loads, such as wheel axles, shafts, push rods and so forth in for example motor vehicles, tractors and road-building machines. It is a known fact that workpieces of this type are always subjected to reverse bending loads and in many instances also to dynamic torsion, possibly at the same time.

The object of the invention is to improve the methods hitherto used for straightening elongated metal workpieces, in which the bent workpiece is partly or wholly inductively heated and at the same time an electromagnetically generated straightening force is applied which presses the workpiece against stops or other straightening tools to straighten the workpiece, and finally cooling the straightened workpieces.

The particular advantage afforded by the method of the invention, is that straightening introduces no additional stresses into the straightened workpiece. Consequently workpieces that have been treated according to the method of the invention are capable of carrying higher reverse bending and/or torsional loads.

By the method of the invention, hot straightening is effected with the aid of induction currents which pass axially through the workpiece while this is supported at one or several points along its length by rollers or other straightening tools, and which in cooperation with the inductor currents generate a straightening force. With steel workpieces this straightening force operates in the temperature range below the Curie point in the form of a pull towards the inductor. With workpieces made of other metals or steel, at a temperature above the Curie point straightening forces arise which tend to push the workpiece away from the inductor. Thus the straightening tools, e.g., the rollers, stops or the like, must be located either between the workpiece and the inductor or on the side of the workpiece facing away from the inductor, according to the metal of which a workpiece is made and the temperature to which the elongated workpiece is to be heated for straightening.

In a development of the method of the invention, the workpiece which is being inductively heated and submitted to an electromagnetically generated straightening force, is simultaneously hardened on one of its surfaces or throughout its cross section by quenching. With steel workpieces it is preferred that the workpieces should be heated for straightening to a temperature above the AC_3 transformation point. This feature provides the advantage that not only the generation of undesirable stresses during hot straightening is avoided, but that all the radial, axial and tangential stresses which are generated during the inductive overall surface hardening of the workpiece are completely preserved.

The magnitude of the straightening force applied to the workpiece naturally depends upon the magnitude of the current in the inductor and upon the magnitude of the eddy current induced in the workpiece. The higher the currents which flow in opposite directions in the inductor and in the workpiece the greater will be the straightening force. Their frequency is also a significant factor since for achieving a given heating effect with a given type of inductor the heating current varies inversely as its frequency. Thus in some applications it may be desirable in the course of the inductive treatment, to reduce the frequency of the heating current, whereby the straightening force may be increased. This step may be followed by a period of operation at higher frequency. In this procedure the straightening force will then be particularly high when the frequency is reduced and since the workpiece is then in a state of reduced strength, at least in its surface regions, the straightening force can take full effect. The final period of higher frequency heating may be useful for achieving particular temperature changes during the final surface hardening process.

Embodiments of the invention are hereinafter described and illustrated in the accompanying drawings, of which:

FIG. 1 schematically illustrates a cross section of an arrangement for performing the method according to the invention for treating nonferromagnetic workpieces or ferromagnetic workpieces which are heated to a temperature above the AC_3 point;

FIG. 2 schematically illustrates a cross section of another arrangement for treating ferromagnetic workpieces which are heated to temperatures not exceeding the Curie point;

FIG. 3 illustrates a particularly useful form of construction of the inductor used in the method of the invention, and

FIGS. 4 and 5 schematically illustrate cross sections of arrangement which allow the method of the invention to be carried out as a continuous process.

Referring to FIG. 1, a linear inductor 2 is provided with a return portion 3 for providing the required magnetic flux, consisting of a stack of laminar plates or of a pressed soft iron magnetic core. A current transient in the inductor 2, return conductor 4 and in the workpiece 1 is indicated by crosses and dots in small circles, the crosses indicating a current into the plane of the paper and the dots in small circles indicating currents emerging from the plane of the paper. If the workpiece 1 consists of a nonmagnetic material or of a material at a temperature exceeding the Curie point, the electromagnetic field will apply to such a workpiece a thrust in the direction of arrow 7, thereby urging the elongated workpiece for instance against two straightening rollers 5 and 6. These stops in the form of straightening rollers are preferably located in the center region of the elongated workpiece, The thrust acting on the workpiece in the direction of arrow 7 and forcing the workpiece against the two rotatably mounted rollers 5 and 6 operates to straighten the workpiece. Preferably the workpiece continues to be rotated in the direction of arrow 8 for a given period of time after the current has been shut off so that after this period of cooling the workpiece becomes completely straightened before removal from the heating device. The rollers may also be provided with drive means.

If the workpiece is very bent, it may be advisable to mount the stops so that they can be advanced towards the workpiece. For straightening such a workpiece 1 the latter is mounted between centers for imparting rotation thereto, the two rollers 5 and 6 having been lowered. The rollers 5 and 6 are not raised in the direction of arrow 9 into contact with the workpiece to thrust the latter into a position corresponding to straightness, until the workpiece has already been subjected to a period of heating and its stiffness been somewhat reduced. The infeed of the straightening rollers 5 and 6 may be performed fully automatically in the course of a predetermined period of time, or it may be controlled be reference to the actual surface temperature of the workpiece 1.

Referring to FIG. 2, if it is desired to straighten workpieces consisting of a magnetic material, account must be taken of the fact that such workpieces experience a magnetic pull in the direction of arrow 17. The inductor in this arrangement is

likewise provided with a return path 13 for the magnetic flux. The return conductor for the inductor current is indicated at 14. The straightening pull which now acts in the direction of arrow 17 urges the workpiece 11 against the two rollers 15 and 16, which in this instance are located on the inductor side of the workpiece. The straightening pull in the direction indicated by arrow 17 thus causes the workpiece rotating in the direction of arrow 18 to be straightened. The magnitude of the current should be so chosen that the Curie point will not be exceeded. When the straightening process has been completed rotation of the workpiece may be continued for a period of time in the absence of a current until the workpiece has cooled to a desired temperature level. Cooling need not generally be continued down to room temperature, and the workpieces may be taken out of the straightening machine when they are still at a temperature of 200° to 400° C. For straightening particularly crooked workpieces the straightening rollers 15 and 16 may be mounted in a manner similar to that described with reference to FIG. 1, permitting them to be advanced towards and withdrawn from the workpiece. The straightening rollers may also be driven.

FIG. 3 illustrates a form of construction of inductor which is particularly useful for a large number of applications, and which permits the heating effect and the forces generated by the currents to be further increased. In this arrangement the principal conductor of the inductor 22 is surrounded by the magnetic return portion 23, whereas the return conductor is divided into two components 24' and 24'' located on each side of the magnetic return portion, This arrangement provides improved guidance to the currents induced in the axial direction of the workpiece. Besides the principal magnetic thrust 22' secondary thrusts 25' and 25'' are generated, which together have a significantly improved straightening effect on the workpiece.

When the proposed method and the described apparatus are to be included in a production line at is preferred to make use of an arrangement such as that shown in FIG. 4. Suspended in a vessel 31 filled with a quenching liquid 32, in an indexable drum 33 for mounting horizontally elongated workpieces 34. FIG. 4 is an end-on view of this drum which is rotatable about its center axis 35 and which contains three or more mounting means. The workpieces 34 in each mounting means are supported by rollers 35 which participate in the indexing motions of the drum through angles of 120 °, 90°, 60° or 45°, according to the number of mounting means. The inductor and its accessories are fixed at 36. In this station the workpieces are heated for straightening and possibly further heated to hardening temperature. At the end of a period of time to which a time delay relay may be adjusted, or in dependence upon the actual surface temperature of the workpiece, the drum is indexed 90° in the direction of arrow 37, thereby immersing the workpiece 34 including the straightening rollers 35 in the quench 32. A supplementary sprayer head 30 may be provided to accelerate the rate of quenching. Preferably rotation of the workpiece about its axis in the direction of arrow 39 is continued in the quench. Rotation in the reverse direction may be arranged. The indexing times of the drum are determined by the heating times, since the time available for quenching is at least three heating periods if the drum is provided with four mounting stations. By providing the drum with more heating stations the quenching times in relation to the heating times can be considerably lengthened.

Instead of mounting the workpieces horizontally, an analogous arrangement may provide for vertically mounting the workpieces as illustrated in FIG. 5. The workpieces 41 are heated by an inductor 43 at the first station of the indexable drum, the straightening thrust being directed towards the rollers 43. When the straightening process has been completed the drum in this embodiment is indexed 90°. While the workpiece continues to be rotated in the direction of arrow 45 its surface is quenched by a sprayer head 44. After further indexing of the drum through another 90° quenching can be continued by a sprayer head 46 while rotation of the workpiece in the direction of arrow 45 still continues. At the next station the workpiece 41 can then be removed from the apparatus.

What is claimed is:

1. Apparatus for straightening an elongated bent metal workpiece comprising:
- straightening stop means
- means for mounting an elongated workpiece having at least substantial rotatory symmetry and for rotating said workpiece about its rotatory axis
- inductor means including at least one heating conductor extending in the direction of said rotary axis for carrying an AC current for inducing a current in successive portions of said rotating workpiece so that the induced current heats said successive portion and further so that said AC current generates, together with the induced currents, a force which causes said workpiece to be thrust against said straightening stop means and straightened.

2. Apparatus for straightening an elongated bent metal workpiece as in claim 1 wherein said mounting means including a plurality of workpiece-receiving stations provided on a rotatable drumlike element, and further including a quenching bath and indexing means to rotate the said drumlike element whereby the workpiece-receiving stations may be moved in succession from a heating station to a predetermined position in the said quenching bath.

3. Apparatus for straightening an elongated bent metal workpiece as in claim 1 wherein said workpiece retains ferromagnetic properties for the duration of the straightening treatment and said straightening stop means in located so as to be interposed between a workpiece in its heating position and said inductor means.

4. Apparatus according to claim 1 in which the said straightening stop means are rollers.

5. Apparatus according to claim 4 including drive means for rotating the said rollers.

6. Apparatus according to claim 1 wherein said straightening stop means are adjustably movable towards or away from the workpiece.

7. Apparatus according to claim 6 wherein the movement of the said stop means to and from the workpiece is controlled by control means responsive to predetermined time intervals or to the surface temperature of a workpiece being heated.

8. Apparatus for straightening an elongated bent workpiece as in claim 1 wherein said workpiece is of nonferromagnetic metal, and said straightening stop means is located so as to be on the side of a workpiece in its heating position which faces away from said inductor means.

9. Apparatus as in claim 1 including means for rotating said workpiece so that said current is induced in successive portions of said workpiece as said workpiece rotates.

10. Apparatus as in claim 1 wherein said current induced in said workpiece heats said workpiece to its hardening temperature and including means for quenching said workpiece.

11. Apparatus as in claim 1 wherein said inducing means includes a first conductor extending along the length of said workpiece, a second return conductor connected to said first conductor and extending along the length of said workpiece and magnetic flux path means extending along the length of said conductor.

12. Apparatus as in claim 11 wherein said flux means separates said first conductor from said second conductor.

13. Apparatus as in claim 11 further including a third return conductor connected to said first conductor and extending along the length of said workpiece.

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