METHOD OF HARDENING THE BORES OF CYLINDRICAL MEMBERS

Fig. 1

Fig. 6

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Fig. 4

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METHOD OF HARDENING THE BORES OF CYLINDRICAL MEMBERS

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This invention relates to the heat treatment of the surfaces of cylindrical members and more particularly to the hardening of surfaces of cylinder bores, liners, and the like by electrical induction heating. This is a continuation-in-part of my application Serial No. 450-739, filed August 18, 1954, and now abandoned.

In the hardening of cylinder bores and liners no process is economically feasible unless the process can be carried out and completed without resulting in a distortion of the shape or diameter of the surface of not more than 0.0002". If it were economically possible to use a final grinding or honing operation upon the finished hardened surface of the bore, then a limited amount of distortion over and above that mentioned above could be tolerated, but, for economic reasons, all that one can afford to do after the hardening operation is completed is to take one single pass from a hone through the bore, which is then assumed to be of sufficient accuracy to be used to build up an engine. Such a single pass from a hone would take not more than a few seconds, and therefore is economically tolerable from the overall cost point of view.

An object, therefore, of the present invention is the provision of a method of hardening cylinder bores, liners and the like by electrical induction heating whereby a minimum distortion in the hardening process is obtained.

Moreover, particularly, it is an object of the present invention to provide a method of hardening cylinder bores with minimum distortion by utilizing an exceptionally high frequency induction current whose frequency is of the order of 350 kcs. to 1 megacycle rather than the 10 kcs. or so which have been used in the induction heating processes of the prior art.

Still another object of the invention is the provision of a method as set forth in the preceding paragraphs which is particularly well adapted to the hardening of cast iron cylinder bores and liners as well as to the hardening of steel liners and the like.

Other objects and their attendant advantages will become apparent from the following detailed description read in conjunction with the accompanying drawings wherein:

Fig. 1 is a schematic view showing a machine by which the method of the present invention may be practiced;

Fig. 2 is a bottom plan view of the induction heating head and support of the machine of Fig. 1;

Fig. 3 is a vertical cross-sectional view of the head taken substantially on the line 3—3 of Fig. 2;

Fig. 4 is a view similar to Fig. 3 but taken on the line 4—4 of Fig. 2;

Fig. 5 is an enlarged horizontal cross-sectional view taken on the line 5—5 of Fig. 4; and

Fig. 6 is an enlarged detailed view showing a manner of clamping the induction heating ring against expansion.

In carrying out the invention it is essential that the cylinder block of liner be first stress-relieved so as to eliminate internal stresses, otherwise the subsequent hardening operation could cause bore distortion. A suitable method of stress-relieving a cylinder block, for example, as distinct from annealing, comprises slowly heating the block or liner over a period of about one hour to a temperature of 500° C. and slowly cooling it through a like period. The actual time cycle would be dependent upon the weight and geometric form of the cylinder block or liner. This stress-relieving operation is best carried out after the surfaces of the block have been broken by rough machining, but obviously this operation may be done before any machining is carried out, if so desired. The stress-relieving operation may be carried out by any suitable method, but electric heating may be found most convenient in view of the low temperature required.

The block or liner is then finish machined in every respect, the bores being to final size and finish before passing to the hardening process.

Referring to Fig. 1 of the drawings, the stress-relieved liner 10, the cylinder bore of which is indicated at 12, is positioned alongside the apparatus for carrying out the bore hardening process, which apparatus is indicated generally by the reference numeral 14. The cylinder 10 is preferably positioned on and clamped to a horizontally rotatable platform 16 which may be accurately and uniformly rotated beneath the apparatus 14. The platform 16 and hence the liner 10 may then be rotated at a suitable predetermined speed by a motor 18 during the hardening process.

The hardening apparatus 14 incorporates an inductor heating unit 20 which can be adjusted or lowered to cause it to traverse the bore 12 of liner 10 for which purpose said inductor unit is indicated in the drawings as being attached to the lower end of an insulated guide portion 22 depending from a carriage 24 which is slideable vertically in guides 26. Means for raising and lowering the carriage 24 are indicated in the drawings as a rack 28 secured to the carriage 24 and in mesh with a pinion 30 rotatable by a driving pinion 32, reversal of the direction of rotation of the pinion 32 effecting opposite movements of the carriage 24.

No novelty is claimed in the apparatus so far described, and it is obvious that many different forms of mechanism could be devised for effecting the requisite vertical movements of the inductor unit 20, in the operation of which mechanism it is desirable that the inductor unit 20 be traversed downwardly at a rate equal to the lowest point of the cylinder bore 12 to which the hardened zone is required to reach, and that the motion of the inductor unit is then reversed, and it starts to traverse upwardly at a predetermined rate of travel, which motion changes can be effected automatically by generally well-known mechanisms, involving, for example, cam-operated reversing switches controlling an electric driving motor 18.

Referring now to Figs. 2 and 4, the inductor unit 20 comprises a cylindrical non-magnetic body 34 having a single-turn peripheral inductor ring 36 whose ends are connected to the respective extensions 38, 40 which are attached to current supply conductors 42, 44 respectively, these conductors being separated by a thin sheet of insulating material 46, such as mica. The inductor ring 36 is preferably triangular in cross-section, coolant water during operation being circulated therethrough by way of extensions 38, 40 which are connected to the opposite ends of the ring by way of horizontal passages 48, 50 as shown in Fig. 5. Desirably, coolant water will flow downwardly through each of the extensions 38, 40 and will escape from the inductor ring through a vertical passage 52 shown in Fig. 4 which is connected to the interior of the ring by way of a triangular cham-

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ber 54 and a series of drain holes 56 in the inductor ring on the side thereof opposite its points of connection with horizontal passage 48, 50. Immediately below the level of the inductor ring 36, the body 34 of the unit is formed with an internal annular coolant passage 58 to which lead feed pipes 60 having connections 61 at their upper ends for the coolant, which may be water. A ring of coolant emission openings 62 connect the body 34 of the inductor unit, said ring of openings being immediately below the inductor ring 36. To insure escape of coolant to below the heating unit an annular series of drain holes 63 are provided in a flange at the bottom of the head.

Referring now to Fig. 6, in utilizing the exceptionally high frequencies in accordance with the invention, it is desirable to maintain an absolute uniform spacing of the inductor ring 36 from the cylinder wall. Since the ring will tend to expand upon application of heat, the method of the present invention contemplates positively preventing such expansion by providing annular clamping means for the ring. This may be accomplished by providing grooves 64 in head 34 for receiving in clamping relationship the truncated apices of the inductor ring 36 as clearly illustrated in Fig. 6.

In carrying out the method of hardening the surface of the cylinder bore 12, the inductor unit 34 traverses downward at a rapid rate to the lowest point in the bore 12 to which a hardened zone is required to reach, and at this predetermined point the motion of the unit 34 reverses and it commences to traverse upwardly at a predetermined rate. At the same time the current supplied to high frequency inductor ring 36 is switched on, and also the supply of coolant to the inductor ring and to the passage 58 and emission openings 62 is commenced.

During the upward traverse of the inductor unit 12, the surface of the cylinder bore is progressively heated to hardening temperature by the local heating effect of the travelling inductor ring 36, and the heated surface is progressively quenched by means of the coolant emerging radially from the emission openings 62.

This continues until the top edge of the hardened zone of the bore 12 is reached, at which the speed of traverse is increased and the current and coolant supply is switched off. The inductor unit 37 then returns to the starting point and is ready for the next hardening operation.

In order to achieve surface hardening with minimum distortion, that is to say-distortion not in excess of 2%000", the method of the invention contemplates in the first instance the use of a current frequency of an exceptionally high order of from 350 kcs. to 1 megacycle. This is a most important feature of the present invention and I have discovered by the use of such frequencies it is possible to use induction hardening methods for hardening the cylinder surfaces of cast iron cylinder blocks and liners as well as steel liners on an economical production basis involving no more than one pass of a honing machine to remove whatever slight distortion may result up to the desired and achieved minimum of 2%000".

By the use of high frequency current in the range of 350 kcs. to 1 megacycle a very thin casing of hardness is achieved on the order of 2%000" and this permits a speed of heating head traverse such that quenching fluid can be effectively applied following the head which results in extreme hardness and a minimum amount of distortion.

An important factor in obtaining minimum distortion coupled with maximum speed for the process resides in an extreme accurate construction of the inductor. The inductor itself is desirable of a minimum width to localize the coupling between it and the portion of the bore over which it is traveling, and owing to the fact that in actual practice it is carrying an input load of approximately 40 kws., it must be backed by a vigorous flow of cooling water to enable it to do so without melting.

Furthermore, the input and output ends of the inductor should be adequately insulated from one another and they may, if desirable, be scarfed, or overlapped, in such a way that a continuous circular ring of coupling is put into the bore, otherwise a line of unhardened material will be produced. This is, of course, not necessary if the bore can be rotated during the operation of hardening as above described but this is not always practicable if the hardening operation is being carried out on a cast iron cylinder block.

As has been mentioned, it is also necessary to avoid expansion of the inductor ring during the process of hardening, and therefore the inductor construction must be such that it is clamped firmly in position parallel to the traverse of the inductor through the bore. It is also found that the quench orifices beneath the inductor and traversing with it through the bore should be very closely positioned and accurately controlled, otherwise it would be impossible to get a reasonable hardness from a material such as cast iron. For reasonable efficiency, it is obvious that good coupling between the inductor and the bore is necessary and this can be obtained if the gap between the two is not more than 2%000".

To illustrate the practical application of the method of the invention, a 3" diameter bore of a cylinder liner whose surface is to be hardened by the apparatus illustrated in the drawings would be rotated at a speed of 80 r.p.m. and the heating head with a current operating in a frequency range of between 350 kcs. and 1 megacycle would traverse the cylinder bore from the lower end of the surface to be hardened to the upper end thereof at a speed of 1 foot in twenty seconds. This produces sufficient undistorted hardness to insure 100,000 miles of operation before appreciable wear can be detected. As has been mentioned before, prior to the hardening operation, the liner would have been stress-relieved and machined accurately to finished size. Since the hardening process of the invention does not produce distortion exceeding 2%000", should distortion up to this amount appear, such can be readily taken care of by a single pass of a honing machine.

It is believed that it should now be apparent that the present invention by utilizing an exceptionally high frequency induction heating current has produced a practical, economical, high speed production method for hardening the cylinder bores of cast iron or steel cylindrical members such as the inductors, blocks or the internal surface of steel or cast iron liners. The invention is particularly suited to the hardening of cast iron members because the exceptionally high frequency enables the attainment of hardening temperature to be confined to a thin skin of iron immediately surrounding the bore, the radial extent of intense heating being thus limited, distorting temperatures cannot penetrate the otherwise readily heat-distorted cast iron and thus the major portion of these members, except for the hardened casing, are essentially unaffected by the process of the invention.

What is claimed is:

The method of surface hardening the bore of a cylindrical member to provide a hardened surface of approximately .025" in depth and with a distortion not exceeding .002" comprising the steps of stress relieving the member by heat, and subsequently cooling the member, machining the bore to final dimensions, hardening the bore with a single turn inductor ring having a width extremely narrow with respect to the length of the bore, circumferentially clamping said ring to positively limit radial expansion thereof when heated, providing a gap of not more than .002" between said ring and said bore, circulating cooling medium continuously through said inductor ring to prevent distortion thereof during heating, applying high frequency electrical current to said induc-
tor ring as it traverses said bore, said frequency being not less than 350 kcs., and continuously applying cooling liquid to quench said bore immediately after application of heat thereto by said inductor ring as it traverses said bore.

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