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F. C. EMERY ET AL

2,318,145

METHOD OF FLAME HARDENING TUBULAR STRUCTURES

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FIG. 1.

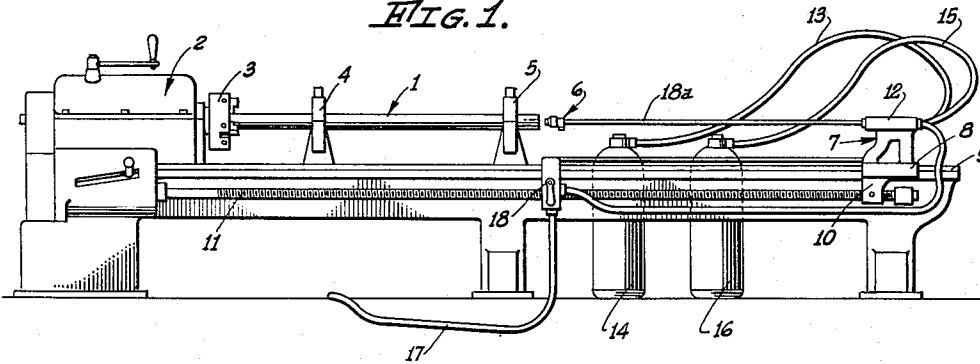


FIG. 2.

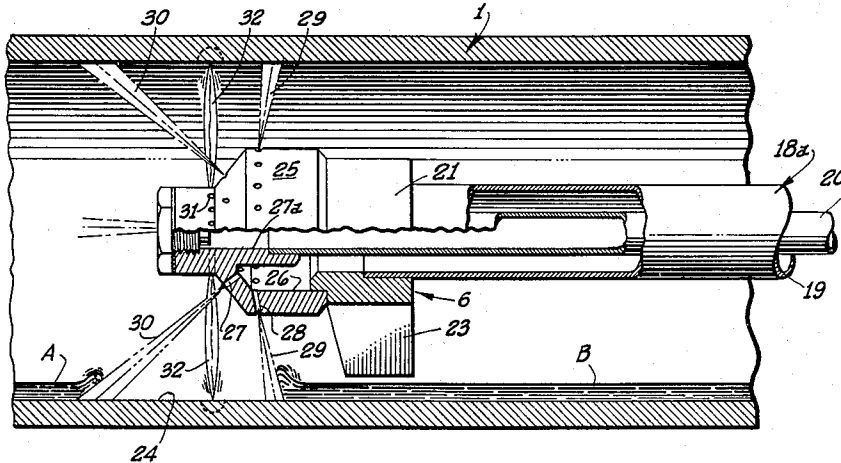
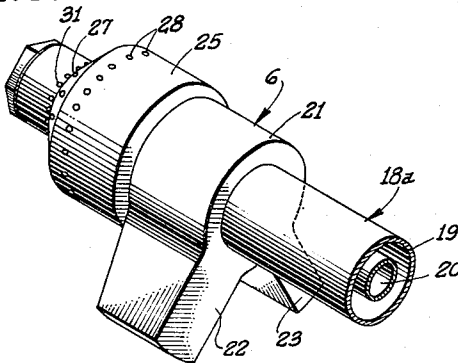


FIG. 3.



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METHOD OF FLAME HARDENING
TUBULAR STRUCTURES

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6 Claims. (Cl. 148—21)

Our invention relates to the hardening of the interior of bores in metal structures and has particular reference to a simple and ready method for securing the desired degree of hardness by controlled heating and quenching of the surface metal on the interior of such bores.

In the manufacture of various types of machinery, it is frequently desirable to provide bores therein, the interior surfaces of which are required to be hard and wear resistant, particularly when such bores are to constitute elements in which other machine elements or parts are to be moved such as engine cylinder and piston assemblies, pump cylinders, barrels and the like within which plungers or pistons operate, and many other machine elements of like character, in which the surfaces of the bores should be hardened while the remainder of the body of metal structure within which the bore is located need not be of especially hard character. Heretofore, it has been the common practice to line such bores with sleeves or liners of hard material which is expensive both of labor and material.

Attempts have been made to surface harden such bores directly as by case-hardening or nitriding, both of which processes involve expensive equipment, additional material for furnishing the chemicals required for producing hardness and the consumption of much time required for completing the processes. Further, the results are not entirely satisfactory due to the inability to reasonably control uniformity of penetration of the heat to the body metal and the resultant creation of undesired stresses in the body of the machine or machine element.

Such disadvantages are particularly apparent in attempts to surface harden the interior of long bores wherein the problems of uniform heating and uniform quenching are especially difficult as well as requiring expensive handling equipment and machinery to accommodate the machines or machine elements in which such bores are located.

One example of the deficiencies of the previous methods and one which presents particularly vexing problems which may be solved by employing our invention is that of the treatment of the interior surfaces of thin walled tubular structures such as may be used as barrels or cylinders for pumps or as liners for piston and cylinder assemblies, especially long stroke small diameter pumps such as are employed for deep well pumping operations.

Such pump barrels or liners are frequently of relatively great length, ranging from six to twenty or more feet while the internal diameters may be as small as one inch and the wall thickness may be as low as one-eighth inch. It is obvious that machinery and equipment for case hardening or nitriding of such pieces of appa-

ratus would be expensive to install and to maintain in addition to the inability to control the uniformity of heating and quenching such lengths and diameters of bores and yet it is extremely desirable that such structures be provided with uniformly hardened interior surfaces against which the plungers of such pumps may operate. Because of the difficulties heretofore presented, it has been the common practice in that industry to form the barrels of larger internal diameter than is required by the plunger and to line the interior of the barrel with liners which will provide the necessary hardened surface.

While it will be understood by those skilled in this art that our invention is not limited to the treatment of this or any other specific apparatus, this specific example is selected as presenting additional problems and difficulties which may be solved by the use of our method and thus more effectively illustrates the advantages of our method.

Since the metals used for pump barrels and other machine elements (steel being ordinarily employed) often contain considerable carbon, it is feasible to surface harden bores in these elements by merely heating and quenching the interior surface. Metals other than steel may also be hardened in much the same manner by supplying the particular element required (corresponding to the carbon in the steel) to the metal at the time it is heated. Prior to our invention, the attempts which were made to achieve the desired hardening of the interior surfaces of bores have been characterized by the vertical disposition of the tube during the time it was processed and by the application of a relatively small flame to the interior of the tube which was moved upwardly through the tube and was closely followed by a jet of cooling medium, such as water, for the purpose of quenching and hardening the previously heated surface.

These attempts at flame hardening the interior surfaces of bores have not been successful because the metal ahead of the flame pre-heats due to conduction of heat away from the location of the flame and causes uneven heating of the surface. This uneven heating often results in a non-uniformly hardened surface having relatively soft and extremely hard spots therein. Furthermore, it has been found very difficult to keep a flame continuously burning within the bore since the combustible gases are often preheated to ignition temperatures before they reach the burner so as to cause a flash-back within the supply lines. The resulting miniature explosion immediately snuffs out the flame.

It is accordingly an object of our invention to overcome the above noted disadvantages by pro-

viding a method of flame hardening the interior surfaces of bores in machine elements.

It is also an object of our invention to provide a method of flame hardening the interior surfaces of bores in machine elements which consists in passing a flame through the bore, limiting the area of flame contact to a relatively short length cylindrical zone, cooling the portion of the surface ahead of the flame to prevent pre-heating, and quenching the surface as it is heated.

It is also an object of our invention to provide a method of flame hardening of the character set forth in the preceding paragraphs, in which the combustible gases are cooled to prevent premature ignition thereof and the extinguishing of the flame.

It is also an object of our invention to provide a method of flame hardening of the character set forth in the preceding paragraphs, in which the combustible gases comprise a mixture which will support combustion sufficiently for the maintenance of the flame irrespective of the character of atmosphere within the bore.

It is also an object of our invention to provide a method of flame hardening of the character set forth in the preceding paragraphs, in which the bore is disposed horizontally and rotated about its axis to evenly distribute the cooling medium throughout the length thereof and to provide for uniform heating of the interior of the bore.

It is also an object of our invention to provide a method of flame hardening of the character set forth in the preceding paragraphs, in which the depth and degree of hardening may be continuously controlled.

It is a still further object of our invention to provide a method of flame hardening of the character set forth in the preceding paragraphs, in which the degree of hardening and the depth to which the hardening process penetrates is controlled by regulating the rate of flow of the cooling medium supplied to the area being treated.

Other objects and advantages of our invention will be apparent from a study of the following specifications, read in connection with the accompanying drawing, wherein:

Fig. 1 is an elevational view of one form of apparatus which may be employed in performing the method of our invention;

Fig. 2 is an enlarged fragmentary longitudinal section illustrating the manner in which one form of mechanism operates according to the method of our invention to provide a hardened surface on the interior of a relatively small bore tube; and

Fig. 3 is a perspective view of one form of combination burner and spray head which may be employed in the practice of the method of our invention.

Referring to the drawing, we have illustrated the application of the principles of our invention to one typical example of surface hardening as applied to the hardening of the interior of small bore, long length thin walled tubes adaptable for use as barrels for deep well pumps and have illustrated apparatus which may be employed for the practice of our invention, which apparatus is described in detail and claimed in our copending application Serial No. 301,923, filed October 30, 1939, now Patent 2,279,564, dated April 14, 1942.

In Fig. 1 a relatively long length of small bore tubing 1 is illustrated as being horizontally sup-

ported for rotation about its own longitudinal axis. This type of support may be conveniently afforded by the employment of the conventional engine lathe 2, one end of the tubing 1 being secured by means of a lathe chuck 3 to the conventional spindle rotating mechanism of the lathe.

The mid portion and outboard end of the tubing 1 may be supported by means of steady rests 4 and 5. The carriage and tool post assembly of the lathe 2 may be employed for supporting a combination burner and spray head 6. However, as illustrated in Fig. 1, we prefer to employ a special carriage 7 which includes a guiding portion 8 which cooperates with the bed 9 of the lathe 2 to guide the carriage 7 for a longitudinal sliding movement along the bed. A downwardly depending portion 10 of the carriage 7 is adapted to cooperate with the feed screw 11 of the lathe 2 to provide a continuous and constant rate of travel of the carriage 7 along the length of the bed 9. The carriage 7 is provided with a head portion 12 which may constitute a mixing chamber for mixing in the proper proportions oxygen delivered by means of a flexible hose 13 from an oxygen supply tank 14 with a combustible gas such as hydrogen or acetylene delivered by means of a hose 15 from a gas supply tank 16. Additionally, a cooling medium is conveyed to the mixing head 12 by means of a supply line 17 in which may be interposed a control valve 18 adjustable to regulate the rate at which the cooling fluid is supplied to the combination burner and spray head 6. The burner and spray head 6 may be supported upon the carriage 7 in axial alignment with the bore to be treated by means of a tubular supporting member 18a which may be advantageously constructed along the lines illustrated in Fig. 2.

As illustrated in Fig. 2, the supporting member 18a preferably comprises an outer tube 19 within which is concentrically mounted an inner tube 20. The inner tube 20 is connected to the mixing chamber 12 and is adapted to pass the combustible mixture of gases to a burner portion of the combined burner and spray head 6. The annular space between the inner tubing 20 and the outer tubing 19 may be thus utilized as a conduit for conducting the cooling medium to the spray head.

The combined spray head and burner 6 may be advantageously constructed along the lines illustrated in Figs. 2 and 3, in which the head 6 is illustrated as including a body portion 21 secured to the outermost end of the tubular supporting structure 18a and provided with a pair of feet members 22 and 23 adapted to ride upon a lower interior surface 24 of the bore to support the head 6 substantially concentrically therein.

To the body portion 21 may be affixed a head structure 25 which defines an interior space 26 communicating with the annular space between the inner tubing 20 and the outer tubing 19 so as to be supplied with cooling medium conducted through this space. The head structure 25 is provided with a pair of sets of openings 27 and 28 communicating between the space 26 and the exterior of the head structure 25.

Each of the set of openings 28 is preferably adapted to discharge individual streams of cooling medium 29 rearwardly along the tube and may accordingly be rearwardly inclined. The other set of openings 27 is preferably oppositely inclined so that streams of cooling fluid 30 therefrom are directed forwardly along the bore. The

head structure 25 preferably also defines a gas space 27a which communicates with the interior of the inner tubing 20 so as to receive the mixture of combustible gases conducted thereto by the tubing 20.

The head structure 25 is provided with a third set of openings 31 which are disposed ahead of the sets of openings 27 and 28 and which communicate between the exterior of the head structure and the gas space 27a. The openings 31 constitute the burner openings and the combustible mixture of gases which are discharged therethrough are ignited as they escape from the openings 31 to form a multiplicity of narrow needle-like flames 32 directed substantially normally against the interior surface 24 of the tubing 1. The set of burner openings 31 is so disposed and directed relative to the sets of spray openings 27 and 28 as to cause the flame 32 to strike the interior surface of the bore upon a short zone lying between the zones at which the spray jets 29 and 30 strike this interior surface.

In the practice of the method of flame hardening of our invention, the equipment is preferably set up in the manner described and as is illustrated in Fig. 1. The rate of flow of oxygen and acetylene is preferably adjusted in any convenient manner and the burner ignited. A flow of cooling medium, water being preferably employed, is started by means of the control valve 18. The tubing or other machine element is rotated by means of the lathe 2 and the feed screw is engaged to cause the carriage 7 to advance to the left, as illustrated in Fig. 1, and slowly move the head 6 longitudinally through the bore.

It will be observed that as the head is moved longitudinally through the bore the jets of water 30 precede the flame 32 and the force of these jets operates to force water delivered by them forwardly along the bore to be discharged out of that end which is secured in the lathe chuck 3 so that a continuous stream A of cooling water is passed along the bore in advance of the burner head 6. In a similar manner the rearwardly directed jets 29 operate to cause a continuous stream B of water to flow from the location of the head 6 toward the rear of the bore where it is discharged out of that end which is supported by the steady rest 5. The rotation of the tube or other machine element causes the streams A and B to wash the entire interior surface of the bore so as to thoroughly and uniformly cool this surface. The jets 30 and the stream A preceding the flame 32 as it is moved longitudinally through the bore operate to keep the forward portions of the bore cool to prevent preheating and uneven heating thereof. The jet flame 32 playing upon the inside of the bore heats the area of impingement in the zone between the jets 29 and 30 to a temperature in excess of the critical temperature of the particular metal employed. As the head 6 is moved forwardly, the rearwardly directed jets of water 29 immediately come into contact with this heated portion of the bore, operating in a well known manner to quench the heated metal to cause hardening thereof. After the metal is quenched, the flow of water to the rear along the bore operates to keep the hardened portion of the bore cool to prevent annealing or tempering of this hardened portion.

Attention is called to the fact that the depth to which the material surrounding the bore is heated to the critical temperature controls the

depth to which the hardening penetrates so that this depth may be readily controlled by controlling the amount of gas which is supplied to the flame 32 and the rate at which the flame is passed through the bore. Furthermore, the degree of hardness achieved depends upon the severity of the quench so that control may be had over the degree of hardness by selection of the proper cooling or quenching medium and the control of the amount applied to the heated zone. It has been found moreover that if the amount of cooling medium which is supplied to the jets 29 and 30 is properly coordinated with the speed of passage of the flame through the bore and the heat of the flame, a controlled tempering of the hardened portion of the interior surfaces of the bore may be obtained, the reheating of the material which causes this tempering operation being obtained by conduction from the highly heated zone contacted by the flame jets 32.

It will be observed that proper coordination between the three variables, namely, rate of gas flow to the flame 32, rate of liquid flow to the precooling and quenching jets 30 and 29, and the rate of travel of the head 6 through the length of the bore, provides a means for controlling the degree of hardness, the amount of tempering effect upon the hardened material, and the depth of penetration of the hardening process. In this fashion a bore in a machine element may be provided with an extremely hard wear resisting interior surface while retaining a tough strong core or body of material surrounding the bore for withstanding shocks and impact loads.

It has been tacitly assumed in the foregoing description that the material of the machine element surrounding the bore being treated was a ferrous metal with some carbon present so that a heating of the metal to above the critical temperature and a quenching of the metal so heated would result in a hardening of the metal. It does, however, lie within the scope of this invention to harden other metals and alloys. Ferrous metals and alloys containing very little or no carbon can be hardened satisfactorily by introducing the carbon at the time the hardening process is carried out, and other metals and alloys may be similarly hardened by supplying whatever element (corresponding to the carbon in steels) is required to permit such treatment to harden the metal. Such hardening elements may be introduced in any of many ways, but we have found that these elements may be readily introduced by addition to the combustible mixture of gases, either in a liquid, vapor, gaseous, or finely divided solid state. For example, in case it is desired to harden a ferrous metal having insufficient carbon to permit the achievement of the desired degree of hardness, additional carbon may be readily added to the metal by employing as the combustible gas a hydro-carbon gas such as acetylene and by supplying an excess of such gas so as to provide a lean, incompletely oxidized flame. A flame of this type is characterized by the presence of very small incandescent carbon particles which are readily received by the surface layers of the heated metal. The additional carbon thus added to these surface layers permits such layers to be hardened by quenching as described.

Attention is called to the fact that the cooling of the combustible gases up to the very point they are discharged from the burner openings, effectively prevents the heating of these gases

to ignition temperatures so as to prevent pre-ignition and consequently effectively prevents the extinguishing of the flame. It is also intended that sufficient oxygen ordinarily be supplied in the combustible mixture of gases so that the flame may be kept burning properly without regard to the character of the atmosphere within the bore.

This method of hardening may also be employed for the economical hardening of a plurality of short length tubes, such as pump cylinder liners, by inserting a plurality of such short tubes within a single long tube. The long tube serves as a carrier for the plurality of short tubes and may be mounted in the lathe 2 in the manner described. The burner 8 is passed through the interior of all of the short lengths and operates in the manner described to harden the interior surface of all of these tubes in a single operation.

While we have shown and described one embodiment of our invention as directed to the hardening of the interiors of pump barrels or similar tubes, it is to be understood that the method of our invention finds great utility in the hardening of the interior surfaces of bores provided in machine elements irrespective of the uses to which such elements may be put, and we do not desire to be limited to any of the details shown or described herein, except as defined in the appended claims.

We claim:

1. The method of hardening the interior surfaces of bores in machine elements which comprises applying heat to the interior surface of the bores to heat said surface to a temperature in excess of the critical temperature, applying a cooling medium to the interior of the bore to confine the effect of the heat to a short cylindrical zone limited in the direction of the length of the bore and to quench and harden said heated interior surface, progressively advancing the zone along the length of the bore, and rotating said element about the axis of said bore disposed horizontally to uniformly distribute the cooling medium over said interior surface.

2. The method of hardening the interior surfaces of bores in machine elements which comprises progressively advancing through the bore a heating element to raise the temperature of the interior surface of the bore to above the critical temperature, progressively advancing a cooling medium through the bore immediately in advance of the heating element to cool the surface and prevent pre-heating thereof, simultaneously progressively advancing a cooling medium through the bore immediately behind the heating element to quench and harden the heated surface, and rotating the element about the axis of said bore disposed horizontally to uniformly distribute the cooling medium over said interior surface.

3. The method of hardening the interior surfaces of bores in machine elements which comprises directing flame upon the interior surface of the bore in a direction radial to the axis of the bore to heat said surface to a temperature in excess of the critical temperature, progressively advancing said flame longitudinally through said bore, applying a cooling medium to the surface of the bore and about the entire periphery thereof immediately in advance of the position of the

flame to prevent preheating of said surface, applying a cooling medium to the surface of the bore and about the entire periphery thereof immediately behind the position of the flame to quench and harden the heated interior surface of the bore, and rotating the element about the axis of the bore disposed horizontally to uniformly distribute said cooling medium over the interior surface thereof.

4. The method of hardening the interior surfaces of bores in machine elements which comprises producing in a horizontally disposed bore a continuous stream of cooling medium extending forwardly along the bore and producing another stream of cooling medium extending rearwardly along the bore, the adjacent ends of said streams being spaced from each other, rotating said element about the axis of said bore to wash the entire periphery of said bore surface with cooling medium to thereby define a short cylindrical zone between said streams which is free of said cooling medium, applying flame to said zone, and advancing the position of said streams and said flame along said bore simultaneously and at a predetermined rate.

5. The method of hardening the interior surfaces of bores in machine elements which comprises advancing from one end to the other of said bore two sprays of cooling medium, one directed forwardly and against the entire periphery of said bore for cooling the interior surface thereof in advance of said spray, and another directed rearwardly and against the entire periphery of said bore for cooling the interior surface thereof behind said spray, rotating said element about the longitudinal axis of said bore disposed horizontally to cause uniform application of said cooling medium to said interior surface, maintaining said sprays in fixed positions relative to each other so as to define a short cylindrical zone disposed between said sprays which is substantially free of cooling medium, and directing flame against said zone for heating said zone to a temperature in excess of the critical temperature, whereby said forwardly directed spray prevents preheating and said rearwardly directed spray quenches and hardens said zone after it is heated.

6. The method of hardening the interior surfaces of bores in machine elements and controlling the depth to which said element is hardened which comprises directing flame against the interior surface of said bore to heat a short cylindrical zone, advancing said flame longitudinally through said bore to advance said zone from one end of said bore to the other at a rate adjusted to heat said zone to a temperature in excess of the critical temperature, controlling the speed of advance of said flame to control the depth to which said zone is so heated, applying a cooling medium continuously to said interior in advance of said zone to prevent preheating of said bore surface, directing said cooling medium against said zone after it is heated to quench and harden the interior surface of said bore, and rotating the element about the axis of said bore disposed horizontally to uniformly distribute the cooling medium over said interior surface.

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