METHOD AND APPARATUS FOR INDUCTIVELY HEATING A WORKPIECE FORMED FROM A HIGHLY OXIDIZABLE METAL

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ABSTRACT OF THE DISCLOSURE

There is provided an apparatus and method for heating a titanium workpiece to its forging temperature without the danger of rapid oxidation of the workpiece. A platform supports the workpiece and is movable between a first and a second position. The first position is in a fluidized-bed of thermoplastic material, and a first induction heating coil heats the workpiece in this first position to a temperature below the forging temperature so that a coating of plastic material is formed on the workpiece. Thereafter, the platform moves the workpiece to the second position where the workpiece, before cooling, is heated to the forging temperature.

This invention pertains to the art of induction heating and more particularly to a method and apparatus for inductively heating a workpiece formed from a highly oxidizable metal.

The present invention is particularly applicable to heating a titanium billet preparatory to forging the billet into an intricate shape, and it will be described with reference thereto; however, it will be appreciated that the invention has somewhat broader applications and may be used for heating workpieces formed from other metals which rapidly oxidize at high processing temperatures. Of course "oxidation" is used as a generic term indicating chemical combination with an active gas, such as oxygen, nitrogen and hydrogen.

Titanium and more especially some of its alloys, has been found to be extremely useful in producing various parts used in the aeronautical and space fields. This usefulness is basically attributable to the high tensile strength of these metals and their relatively low density. For instance, some titanium alloys have a tensile strength approaching 200,000 pounds per square inch which is somewhat equivalent to the tensile strength of alloy steel. At the same time, these titanium alloys have a density between 55% and 60% of alloy steel density. In addition, titanium is one of the most abundant metals found on earth. These factors, in combination with a sharp increase in demand for lightweight metals, have contributed to a rapid growth in the use of titanium and titanium alloys.

When forming titanium, or titanium alloys, often the metal is forged into shape. To accomplish this, the titanium, or titanium alloy, is first formed into a billet, and the billet is heated to the forging temperature, which may often be over 2500° F. Herein lies the major difficulty in the use of titanium, or titanium alloy, for high strength components.

Titanium is a highly oxidizable metal, and when the titanium billet is heated to a high forging temperature, there is an imminent possibility that the billet will ignite or rapidly oxidize. This not only presents a hazard to employees handling the billets, but it also presents a problem in the forging operation. The ignited billets cannot be successfully forged in most instances.

To overcome this difficulty, it has been proposed to heat and forge the titanium billets in a controlled non-oxidizable atmosphere or a vacuum. This method is not highly successful because of the inherent problems in any processing operation requiring a completely protective atmosphere or vacuum. Consequently, it has become somewhat common practice to coat a titanium billet with a protective layer which will not evaporate to an appreciable extent during the heating and forging operation. The coated billet is then heated and forged. This particular method of preventing ignition during the forging operation has proven successful; however, it does involve a substantial preparatory operation which increases the cost of the titanium forging and decreases the productivity of the forging line.

These and other disadvantages of prior attempts to heat titanium billets to a forging temperature without ignition are overcome by the present invention which is directed toward a method and apparatus for heating these billets without requiring a separate and distinct preparatory process for applying the protective coating onto the surface of the billet.

In accordance with the present invention, there is provided an apparatus for heating a workpiece formed from a highly oxidizable metal before the workpiece is forged. This apparatus comprises a chamber having a lower portion filled with a fluidized thermoplastic material capable of coating the workpiece when the workpiece is heated, means for maintaining the fluidized material in a fluid-like condition, a workpiece support, means for moving the support vertically between a first position within the fluidized material and a second position above the fluidized material, a first induction heating coil mounted in the fluidized material and having a central workpiece receiving opening, this coil being adapted to surround the workpiece when the support is in the first position for inductively heating the workpiece to a temperature sufficiently high to fuse some of the fluidized material onto the workpiece to form a continuous protective coating, and a second induction heating coil axially aligned with and above the first coil for heating the coated workpiece to its forging temperature when the support has been moved to its second vertical position.

By using an apparatus as defined above, the workpiece is heated to the coating temperature and, then, heated to the forging temperature. Consequently, there is no necessity for first coating the material, letting it cool, and then reheating the coated workpiece to a forging temperature.

This apparatus substantially reduces the preparatory coating operation by incorporating this operation in the required heating process.

In accordance with another aspect of the present invention, there is provided a method for heating a workpiece formed from a highly oxidizable metal preparatory to forging the workpiece. This method comprises the steps of providing a fluidized bed of a thermoplastic material capable of coating the workpiece when the workpiece is heated, placing the workpiece in the bed, heating the workpiece to a temperature sufficient to fuse the material onto the workpiece to form a substantially continuous protective coating, and, then, heating the workpiece to the forging temperature.

The primary object of the present invention is the provision of a method and apparatus for heating a workpiece formed from a highly oxidizable material, which method and apparatus are economical in use and efficient in preventing oxidation of the workpiece after it is heated.

Other objects and advantages will become apparent from the following description used to illustrate the preferred embodiment of the invention as read in connection with the accompanying drawing in which:

FIGURE 1 is a partially cross-sectional, side elevational view illustrating, somewhat schematically, the preferred embodiment of the present invention; and,

FIGURE 2 is a cross-sectional view taken through a
workpiece which has been heated by the embodiment of the invention shown in FIGURE 1.

Referring now to the drawing wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only and not for the purpose of limiting the same, FIGURE 1 shows an apparatus A for heating a billet or workpiece B. The billet is formed from a highly oxidizable material, such as titanium or a titanium alloy, and the billet is to be forged into a desired shape after being heated by apparatus A. The apparatus includes a chamber 10 having a lower fluidized bed 12 which extends to an upper level 14. The fluidized bed 12 is formed from a finely powdered electrically non-conductive, thermoplastic material which is capable of being fused onto workpiece B when the workpiece is heated to a given temperature. The material forms a continuous coating C on the workpiece. See FIGURE 2. The art of fluidizing various materials is somewhat highly developed, and any person with ordinary skill in this field would appreciate the particular grain size which will allow the thermoplastic material to act as a liquid. Of course, a variety of thermoplastic materials are capable of fusing to workpiece B after it has been heated; consequently, a variety of materials can be used in establishing the fluidized bed 12.

Chamber 10 includes a lower wall 20 having a plurality of spaced inlet pipes 22 which are communicated with a manifold 24. A feed or inlet pipe 26 communicates the manifold with a supply 28 of pressurized gas, such as air, so that the pressurized gas maintains the fluidized bed 12 agitated. A valve 30 is schematically illustrated within the feed pipe 26. This valve can be used to adjust the amount of gas flowing through pipe 22 so that the fluidized bed can be maintained in a fluid-like condition.

In accordance with the illustrated embodiment of the present invention, there is provided a workpiece support 40 having an upper plate 42 with upwardly extending spacer pins 44. The workpiece B is placed on the spacer pins so that the bottom portion of the workpiece is spaced from plate 42 and is exposed to the powdered thermoplastic material within the fluidized bed 12. During the coating operation, which will be hereinafter explained, no coating is applied to the workpiece adjacent the spacer pins 44; therefore, the coating C will be provided with a plurality of indentations 44a, as shown in FIGURE 2. These indentations expose only a small portion of the surface of the workpiece, and they do not present a possible area of rapid, wide spread oxidation. The workpiece support 40 also includes a rod 50 extending downwardly through an aperture 52 in lower wall 20. A seal 54 prevents loss of the fluidized bed through aperture 52.

To reciprocate rod 50, there is provided a lower cylinder 56 which receives a piston, not shown, connected to the lowermost end of rod 50. An operating valve 60, of known construction, is utilized for communicating fluid lines 62, 64 with the proper side of the piston within the cylinder so that the valve 60 controls the vertical movement of rod 50 and, thus, workpiece B. As will be hereinafter explained, the workpiece B is moved by rod 50 between a first, lowermost position as shown by solid lines in FIGURE 1, a second, intermediate position as shown by phantom lines in FIGURE 1 and a third uppermost, loading position also shown by phantom lines in FIGURE 1. The purpose of moving the workpiece B between the three positions will be appreciated after considering the following discussion.

Apparatus A includes a lower multiturn induction heating coil 70 having the conventional internal coolant passage 72 and power leads 74, 76. The leads extend through chamber 10 and are insulated from the chamber by grommets 80, 82. These grommets also provide a seal to prevent the fluidized bed 12. Input or power leads 74, 76 are connected across a high frequency power supply, schematically represented as a generator 84 having output leads 86, 88. Of course, a variety of other high frequency power supplies could be used with-

out departing from the intended scope of the invention. Various accessory equipment for the generator or power supply is not illustrated since this equipment is commonly known in the art of induction heating.

Adjacent the second position of workpiece B, there is provided a multiturn induction heating coil 90. This coil includes internal coolant passage 92 and input leads 94, 96. These leads are insulated from the chamber 10 by grommets 100, 102. A second power supply, schematically represented as generator 104, is connected by power leads 100, 108 onto the inside of coil 90. The generators 84, 104 are substantially identical, and it is within the scope of the invention to provide only one generator with a switching arrangement for selectively switching the generator between coils 70, 90. A plate 109 having a slot 109a is movable across chamber 10 at level 14 to seal and contain the fluidized bed 12. In the retracted position the support 40 can move between the first and second positions.

Referring again to the workpiece support 40, rod 50 is provided with axially spaced cams 110, 112 and 113. A control switch 120 is secured adjacent the rod 50 so that the cams will operate the switch by movement of a follower 122 extending from the switch. The switch 120 controls valve 60 and generators 84, 104. When apparatus A is turned on, by a switching arrangement not shown, the plate 109 is retracted, support 40 moves to the first position, and generator 84 is energized. This energizes coil 70 and starts the initial heating operation of workpiece B positioned within the coil 70. A timing device located within switch 120 allows the workpiece B to heat until a given temperature is reached. This temperature is sufficient to allow the thermoplastic material within the fluidized bed 12 to fuse onto the outer surface of workpiece B. Since the fluidized bed is electrically non-conductive, and the workpiece is conductive, the magnetic field created by coil 70 does not heat this material. Only the workpiece is heated, and material fusion takes place only by the thermoplastic material coming in contact with the inductively heated workpiece. This fusion of the thermoplastic material forms the protective coating C shown in FIGURE 2. Coolant passage 72 maintains the surface of coil 70 below the melting or fusion temperature of the powdered material in bed 12. This prevents a build-up of plastic material on the coil. Thereafter, the timing device causes switch 120 to actuate valve 60 and rod 50. The switching 120 operates the rod 50 moves upwardly, plate 109 is retracted momentarily and valve 30 turns off the gas so that the powder in bed 12 is not blown into the upper portion of the chamber.

During the upward movement of rod 50, cam 112 contacts follower 122. This causes switch 120 to actuate valve 60 in a proper manner to step movement of the rod. The workpiece is now within the central opening of coil 90. In this second position, the coil 90 inductively heats the coated workpiece B to a forging temperature which may vary according to the material forming the workpiece. The timing device within switch 120 determines the heating cycle of coil 90.

After the coil 90 has heated the workpiece for the proper time, rod 50 again starts upwardly until it reaches the loading position. Then cam 113 contacts follower 122, and the rod again stops. The workpiece is removed, and another workpiece is placed on support 40. The support is then returned to its initial position. This position is determined by cam 110 which contacts follower 122 and stops rod 50.

The present invention has been described in connection with one structural embodiment; however, various changes may be made in this embodiment without departing from the intended spirit and scope of the present invention.
5

Having thus defined my invention, I claim:

1. An induction heating apparatus for heating a workpiece formed from a highly oxidizable metal to a forging temperature, said apparatus comprising: a chamber having a lower portion filled with a fluidized thermoplastic material capable of coating said workpiece when it is heated; means for maintaining said fluidized material in a fluid-like condition; a workpiece support; means for moving said support vertically between a first position within said fluidized material and a second position above said fluidized material; a first induction heating coil means mounted in said fluidized material and having a central workpiece receiving opening, said coil means being adapted to surround said workpiece when said support is in said first position for heating said workpiece to a first temperature sufficiently high to fuse some of said material onto said workpiece to form a continuous protective coating thereon; and, a second induction heating coil means axially aligned with and above said first coil for heating said coated workpiece to a forging temperature greater than said first temperature when said support has been moved to said second position.

2. An apparatus as defined in claim 1 including control means for selectively controlling said support moving means, said control means comprising first means for energizing said first coil when said support is in said first position, timer means for maintaining said support in said first position until said workpiece is coated and second means for energizing said second coil when said support is moved to said second position.

3. A method for heating a workpiece formed from a highly oxidizable metal to a forging temperature, said method comprising the following steps:

(a) providing a fluidized bed of a thermoplastic material capable of coating said workpiece when it is heated;

(b) placing said workpiece in said bed;

(c) inductively heating said workpiece to a temperature sufficient to fuse said material onto said workpiece to form a substantially continuous protective coating;

(d) removing said heated workpiece from said bed; and,

(e) before said workpiece has cooled substantially, further inductively heating said workpiece to the forging temperature.

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