

A HEATING APPARATUS FOR FORMABLE METALS**Field Of Invention**

The present invention relates generally to a heating apparatus for formable metals. In particular, the invention relates to a progressive heating apparatus and method for heating formable metals.

Background

Metals can be fabricated using a variation of techniques, for example forming. Depending on the characteristics of the metal to be fabricated, some metals, for example magnesium, requires pre-heating before substantial forming can be performed.

Conventionally, a work-piece made from one of these metals has to be placed into a furnace prior to being fabricated. However, this is a time-consuming process that does not meet the high throughput requirement of a production line. The use of a furnace for heating up the work-piece is time consuming. The need for transfer of the work-piece between the furnace and a forming machine is inefficient when speed is required, especially along a production line.

Alternatively, the die of the forming machine can be pre-heated before forming the metal. However, the unevenness of the face of the die that is used for conducting heat to the metal will result in non-uniform temperature distribution throughout the portion of the metal to be formed. Thermal stresses may be established in the die as a result of temperature gradients across the work-piece, which may lead to a short die life-span.

Hence, this clearly affirms a need for a heating apparatus and method for improving the pre-heating process of a formable metal.



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Summary

A pre-fabricated work-piece made of formable metal is usually planar and elongated. When directly heating a first portion of the work-piece, an adjacent second portion of the work-piece is heated as well through conduction. Consecutively, when the second
5 portion of the work-piece heated, only a short period of time is required for the second portion of the work-piece to achieve a required temperature.

Therefore, in accordance with a first aspect of the invention, there is disclosed a heating apparatus comprising:

10 a heating unit for applying an amount of heat to a first portion of a metal, the first portion of the metal having a current temperature and being positioned at a heating position;

a forming apparatus for forming metals;

a temperature transducer unit for sensing the current temperature of the first
15 portion of the metal, the temperature transducer unit for producing a current temperature signal representative of the current temperature of the first portion of the metal; and

a transfer apparatus for removing the first portion of the metal away from the heating position for transfer to the forming apparatus, the first portion of the metal
20 being formed by the forming apparatus while heat is being applied to a second portion of the metal by the heating unit,

whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by a set-point temperature and the set-point temperature being pre-defined.

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In accordance to a second aspect of the invention, there is disclosed a heating apparatus comprising:

a heating unit for applying an amount of heat to a first portion of a metal, the first portion of the metal having a current temperature and being positioned at a
30 heating position, the amount of heat increasing the current temperature of the first portion of the metal and the first portion of the metal conducting heat to a second portion of the metal, the second portion of the metal being adjacent to the first portion of the metal;

a temperature transducer unit for sensing the current temperature of the first portion of the metal, the temperature transducer for producing a current temperature signal representative of the current temperature of the first portion of the metal;

a forming apparatus for forming metals;

5 a controller for determining an amount of heat necessary for application to the metal so that the current temperature of the metal substantially conforms to a set-point temperature; and

a transfer apparatus for removing the first portion of the metal away from the heating position and positioning the second portion of the metal at the heating position, the first portion of the metal being transferred to the forming apparatus, the first portion of the metal being formed by the forming apparatus while heat is being applied to a second portion of the metal by the heating unit,

whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by a set-point temperature and the set-point temperature being pre-defined.

In accordance to a third aspect of the invention, there is disclosed a heating method comprising the steps of:

20 applying an amount of heat to a first portion of a metal by a heating unit, the first portion of the metal having a current temperature and being positioned at a heating position;

sensing the current temperature of the first portion of the metal by a temperature transducer unit, the temperature transducer unit for producing a current temperature signal representative of the current temperature of the first portion of the metal;

25 removing the first portion of the metal away from the heating position by a transfer apparatus and transferring the first portion of the first portion of the metal to a forming apparatus, the forming apparatus for forming metals; and

30 simultaneously forming the first portion of the metal by the forming apparatus and applying heat to a second portion of the metal by the heating unit,

whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by a set-point temperature and the set-point temperature being pre-defined.

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In accordance to a fourth aspect of the invention, there is disclosed a heating method comprising the steps of:

5 applying an amount of heat to a first portion of a metal by a heating unit, the first portion of the metal having a current temperature and being positioned at a heating position, the amount of heat increasing the current temperature of the first portion of the metal and the first portion of the metal conducting heat to a second portion of the metal, the second portion of the metal being adjacent to the first portion of the metal;

10 sensing the current temperature of the first portion of the metal by a temperature transducer unit, the temperature transducer for producing a current temperature signal representative of the current temperature of the first portion of the metal;

15 determining an amount of heat necessary for application to the metal by a controller so that the current temperature of the metal substantially conforms to a set-point temperature;

removing the first portion of the metal away from the heating position by a transfer apparatus and transferring the first portion of the first portion of the metal to a forming apparatus, the forming apparatus for forming metals;

20 positioning the second portion of the metal at the heating position by the transfer apparatus; and

simultaneously forming the first portion of the metal by the forming apparatus and applying heat to a second portion of the metal by the heating unit,

25 whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by a set-point temperature and the set-point temperature being pre-defined.

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Brief Description Of The Drawings

Embodiments of the invention are described hereinafter with reference to the following drawings, in which:

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FIG. 1 is a front view of a heating apparatus with a first portion of a metal positioned at a heating position and a pair of conducting plates in a close position;

FIG. 2 is a plan view of the heating apparatus of FIG. 1; and

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FIG. 3 is a front view of the heating apparatus of FIG. 1 with the first position of the metal being fabricated by a process equipment, a second portion of the metal positioned at the heating position and the pair of conducting plates in an open position.

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Detailed Description

A heating apparatus and method for addressing the foregoing problems is described hereinafter.

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The heating apparatus is preferably for heating magnesium alloys prior to fabrication. Magnesium has, as its most outstanding characteristic, the lowest density of all structural metals. Magnesium is therefore used where weight is an important consideration, for example as a material for fabricating mobile phone covers.

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Magnesium is relatively soft and has a low elastic modulus due to its hexagonal close-packed (HCP) crystal structure. However, magnesium and its alloys are difficult to deform at room temperature and only small degrees of cold work may be imposed without annealing. Most fabrication of magnesium alloys is either by casting at

temperatures above 600 degrees celcius, warm forming, super-plastic forming or forging at temperatures between 200 and 350 degrees celcius. The heating apparatus used in conjunction with processes for warm forming, super-plastic forming or forging of magnesium.

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An embodiment of the invention, a heating apparatus 20 is described with reference to FIG. 1, which shows a front view of the heating apparatus 20, and FIG. 2, which shows a plan view of the heating apparatus 20. The heating apparatus 20 comprises of a pair of conducting plates 22. Each conducting plate 22 is block-shaped and has a metal mating face 24, the metal mating face 24 being planar. The conducting plate 22
10 has a pair of outwardly opposing side faces 26 generally perpendicular to the metal mating face 24.

A plurality of heating conduits 28 extends from one side face 26 to the other side face
15 26 and having a central axis being generally parallel to the metal mating face 24. Each heating conduit 28 is shaped and dimensioned to accommodate a heating element 30 therein. A plurality of temperature transducer conduits 32, as shown in FIG. 2, extends from the metal mating face 24 through the conducting plate 22. Each temperature transducer conduit 32 is shaped and dimensioned for receiving a
20 temperature transducer 34 therethrough.

Each heating element 30 is electrically connected to a controller (not shown) and for providing heat to the conducting plate 22. The pair of conducting plates 22 is coupled to a clamping assembly 38 with the metal mating face 24 of one conducting plate 22
25 opposing and spaced apart from the metal mating face 24 of the other conducting plate 22. The clamping assembly 38 cooperates with conducting plates 22 for reciprocating the conducting plates 22 in opposing directions along an axis perpendicular to the metal mating face 24.

30 The clamping assembly 38 is electrically connected to the controller, the controller for controlling the clamping assembly 38 to position the conducting plates 22 at either an open position, as shown in a front view of the heating apparatus 20 in FIG. 3, or a close position as shown in FIG. 1. In the open position, the conducting plates 22 are

spaced apart for the passage of a metal 40 therebetween. The metal 40 is preferably magnesium alloy, the metal 40 being planar and elongated in shape.

The metal 40 is held by a transfer apparatus 41 with a first portion 42 of the metal 40 in a heating position (not shown) between the pair of conducting plates 22. In response to the first portion 42 of the metal 40 being placed in the heating position, the clamping assembly 38 brings the conducting plates 22 to the close position. In the close position, the metal mating face 24 of each conducting plate 22 abuts the metal 40.

The controller proceeds to transmit a heating signal (not shown) to the heating elements 30. The heating elements 30 generate heat when the heating signal is received from the controller. The conducting plates 22 conduct heat from the heating elements 30 to the first portion 42 of the metal 40. The conducting plates 22 are shaped and dimensioned for evenly heating the first portion 42 of the metal 40.

The first portion 42 of the metal 40 has a temperature that is sensed by the temperature transducers 34. The temperature transducers 34 produce a temperature signal (not shown) being representative of the temperature of the first portion 42 of the metal 40 for transmission to the controller. The controller compares the temperature signal with a set-point temperature (not shown) that is pre-defined by a user of the heating apparatus 20.

When the temperature of the first portion 42 of the metal 40 is lower than the set-point temperature, the controller continues to transmit the heating signal to the heating elements 30. The controller stops transmitting the heating signal to the heating elements 30 when the temperature of the first portion 42 of the metal 40 reaches the set-point temperature.

Alternatively, a mathematical function is used to generate a temperature margin (not shown) based on the size and dimension of the conducting plates 22, the quantity of heating elements 30 utilised in the heating apparatus 20 and the size and dimension of the metal 40. Using a comparator (not shown), the controller obtains a temperature

difference between the temperature of the first portion 42 of the metal 40 and the set-point temperature. When the temperature difference matches the temperature margin, the controller stops transmitting the heating signal to the heating elements 30.

- 5 Upon the temperature of the first portion 42 of the metal 40 reaching the set-point temperature, the controller signals the clamping assembly 38 to position the conducting plates 22 in the open position. The transfer apparatus 41 then proceeds to remove the first portion 42 of the metal 40 from the heating position. The first portion 42 of the metal transferred to a process equipment 48 for fabrication. The process equipment 48 is preferably a forming machine that requires the metal 40 to be at a formable temperature approximated by the set-point temperature.
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- When the first portion 42 of the metal 40 is being heated, heat is conducted from the first portion 42 to a second portion 50 of the metal 40. The second portion 50 is adjacent to the first portion 42 of the metal 40. Removing the first portion 42 of the metal 40 from the heating position by the transfer apparatus 41 consequently positions the second portion 50 of the metal 40 at the heating position.
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- The temperature of the second portion 50 of the metal has already achieve a portion of the set-point temperature through conduction when the first portion 42 of the metal 40 is being heated by the conducting plates 22. Therefore, it will require a shorter period of time for the temperature of the second portion 50 of the metal 40 to reach the set-point temperature when heated by the conducting plates 22.
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- 25 The aforementioned heating method not only requires a shorter heating time, but also reduces thermal shock induced when too much heat is introduced into the metal 40 within a short time period. This is achieved by progressive heating of the metal 40 using the heating apparatus 20 by segregating the heating process: first by heating the second portion 50 of the metal 40 by conducting heat from the first portion 42 of the metal 40 that is being heated, consequentially by directly heating the partially heated second portion 50 of the metal 40 to the set-point temperature.
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In the foregoing manner, a heating apparatus and method is described according to an embodiment of the invention for addressing the foregoing disadvantages of conventional heat treatment methods and apparatus. Although only one embodiment of the invention is disclosed, it will be apparent to one skilled in the art in view of this disclosure that numerous changes and/or modification can be made without departing from the scope and spirit of the invention.

Claims

1. A heating apparatus for formable metals comprising:

a heating unit for applying an amount of heat to a first portion of a metal, the first portion of the metal having a current temperature and being positioned at a heating position;

a forming apparatus for forming metals;

a temperature transducer unit for sensing the current temperature of the first portion of the metal, the temperature transducer unit for producing a current temperature signal representative of the current temperature of the first portion of the metal; and

a transfer apparatus for removing the first portion of the metal away from the heating position for transfer to the forming apparatus, the first portion of the metal being formed by the forming apparatus while heat is being applied to a second portion of the metal by the heating unit,

whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by a set-point temperature and the set-point temperature being pre-defined.

2. The heating apparatus as in claim 1, the temperature transducer unit comprising:

an array of temperature transducers for sensing the current temperature of the first portion of the metal, each temperature transducer for mounting onto the first portion of the metal.

3. The heating apparatus as in any of claims 1 and 2, the heating unit comprising:

one or more conducting plates for mounting onto the first portion of the metal; and

one or more heating elements received in each conducting plate for providing heat to the conducting plate, the conducting plate conducting heat to the first portion of the metal by conduction.

4. The heating apparatus as in claim 3, each conducting plate comprising:

a metal mating face for contact with the metal, the metal being generally planar; and

a plurality of generally cylindrical conduit extending from the metal mating face through the conducting plate, each conduit having a central axis generally perpendicular to the metal mating face and for the passage of a corresponding temperature transducer therethrough to couple the corresponding temperature transducer to the conducting plate.

5. The heating apparatus as in claim 1, the heating unit comprising:

a pair of conducting plates arranged for reciprocating in opposing directions and for cooperating to clamp the first portion of the metal therebetween; and

one or more heating elements received in each conducting plate for providing heat to the conducting plate, the conducting plate conducting heat to the first portion of the metal.

6. The heating apparatus as in any of claims 1 and 4, further comprising:

a controller for determining an amount of heat necessary for application to the first portion of the metal so that the current temperature of the metal substantially conforms to the set-point temperature, the set-point temperature being defined by a user, and the controller being electrically connected to both the heating unit and the temperature transducer, the controller for receiving the current temperature signal from the temperature transducer, and for providing a heating signal to the heating unit.

7. The heating apparatus as in claim 6, the controller comprising:

a comparator for obtaining a temperature difference between the set-point temperature and the current temperature,

wherein the controller provides a heating signal to the heating elements when the temperature difference is higher than a threshold value, the threshold value being defined by the user and the heating elements providing heat when the heating signal is received.

8. The heating apparatus as in claim 6, wherein the controller provides a heating signal to the heating elements when the set-point temperature is higher than the current temperature, the heating elements providing heat when the heating signal is received.

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9. The heating apparatus as in any of claims 1, 7 and 8, wherein the first portion of the metal conducts heat to the second portion of the metal, the second portion of the metal being adjacent to the first portion of the metal, and the second portion of the metal being positioned at the heating position when the first portion of the metal is removed from the same by the transfer apparatus.

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10. A heating apparatus for formable metals comprising:

a heating unit for applying an amount of heat to a first portion of a metal, the first portion of the metal having a current temperature and being positioned at a heating position, the amount of heat increasing the current temperature of the first portion of the metal and the first portion of the metal conducting heat to a second portion of the metal, the second portion of the metal being adjacent to the first portion of the metal;

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a temperature transducer unit for sensing the current temperature of the first portion of the metal, the temperature transducer for producing a current temperature signal representative of the current temperature of the first portion of the metal;

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a forming apparatus for forming metals;

a controller for determining an amount of heat necessary for application to the metal so that the current temperature of the metal substantially conforms to a set-point temperature; and

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a transfer apparatus for removing the first portion of the metal away from the heating position and positioning the second portion of the metal at the heating position, the first portion of the metal being transferred to the forming apparatus, the first portion of the metal simultaneously being formed by the forming apparatus while heat is being applied to a second portion of the metal by the heating unit,

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whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by the set-point temperature and the set-point temperature being pre-defined.

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11. A heating method for formable metals comprising the steps of:

applying an amount of heat to a first portion of a metal by a heating unit, the first portion of the metal having a current temperature and being positioned at a heating position;

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sensing the current temperature of the first portion of the metal by a temperature transducer unit, the temperature transducer unit for producing a current temperature signal representative of the current temperature of the first portion of the metal;

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removing the first portion of the metal away from the heating position by a transfer apparatus and transferring the first portion of the first portion of the metal to a forming apparatus, the forming apparatus for forming metals; and

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simultaneously forming the first portion of the metal by the forming apparatus and applying heat to a second portion of the metal by the heating unit,

whereby heating the second portion of the metal maintains the first portion of the metal at a set-point temperature, the set-point temperature being pre-defined.

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12. The heating method as in claim 11, further comprising the step of:

providing an array of temperature transducers for sensing the current temperature of the first portion of the metal, each temperature transducer being received in the temperature transducer unit and for mounting onto the first portion of the metal.

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13. The heating method as in any of claims 11 and 12, wherein the heating unit comprising:

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one or more conducting plates for mounting onto the first portion of the metal; and

one or more heating elements received in each conducting plate for providing heat to the conducting plate, the conducting plate conducting heat to the first portion of the metal by conduction.

14. The heating method as in claim 13, wherein each conducting plate comprising:
a metal mating face for contact with the metal, the metal being generally planar; and

a plurality of generally cylindrical conduit extending from the metal mating face through the conducting plate, each conduit having a central axis generally perpendicular to the metal mating face and for the passage of a corresponding temperature transducer therethrough to couple the corresponding temperature transducer to the conducting plate.

15. The heating method as in claim 11, wherein the heating unit comprising:

a pair of conducting plates arranged for reciprocating in opposing directions and for cooperating to clamp the first portion of the metal therebetween; and

one or more heating elements received in each conducting plate for providing heat to the conducting plate, the conducting plate conducting heat to the first portion of the metal.

16. The heating method as in any of claims 11 and 14, further comprising the step of:

providing a controller for determining an amount of heat necessary for application to the first portion of the metal so that the current temperature of the metal substantially conforms to the set-point temperature, the set-point temperature being defined by a user, and the controller being electrically connected to both the heating unit and the temperature transducer, the controller for receiving the current temperature signal from the temperature transducer, and for providing a heating signal to the heating unit.

17. The heating method as in claim 16, further comprising the steps of:
obtaining a temperature difference between the set-point temperature and the current temperature by a comparator, the comparator being received in the controller; and

5 providing a heating signal from the controller to the heating elements when the temperature difference is higher than a threshold value, the threshold value being defined by the user and the heating elements providing heat when the heating signal is received.

10 18. The heating method as in claim 16, further comprising the step of:
providing a heating signal from the controller to the heating elements when the set-point temperature is higher than the current temperature, the heating elements providing heat when the heating signal is received.

15 19. The heating method as in any of claims 11, 17 and 18, further comprising the steps of:
conducting heat from the first portion of the metal to the second portion of the metal, the second portion of the metal being adjacent to the first portion of the metal; and

20 positioning the second portion of the metal at the heating position when the first portion of the metal is removed from the same by the transfer apparatus.

20. A heating method for formable metals comprising the steps of:

25 applying an amount of heat to a first portion of a metal by a heating unit, the first portion of the metal having a current temperature and being positioned at a heating position, the amount of heat increasing the current temperature of the first portion of the metal and the first portion of the metal conducting heat to a second portion of the metal, the second portion of the metal being adjacent to the first portion of the metal;

30 sensing the current temperature of the first portion of the metal by a temperature transducer unit, the temperature transducer for producing a

current temperature signal representative of the current temperature of the first portion of the metal;

determining an amount of heat necessary for application to the metal by a controller so that the current temperature of the metal substantially conforms to a set-point temperature;

removing the first portion of the metal away from the heating position by a transfer apparatus and transferring the first portion of the first portion of the metal to a forming apparatus, the forming apparatus for forming metals;

positioning the second portion of the metal at the heating position by the transfer apparatus; and

simultaneously forming the first portion of the metal by the forming apparatus and applying heat to a second portion of the metal by the heating unit,

whereby heating the second portion of the metal maintains the first portion of the metal at a formable temperature, the formable temperature being approximated by the set-point temperature and the set-point temperature being pre-defined.