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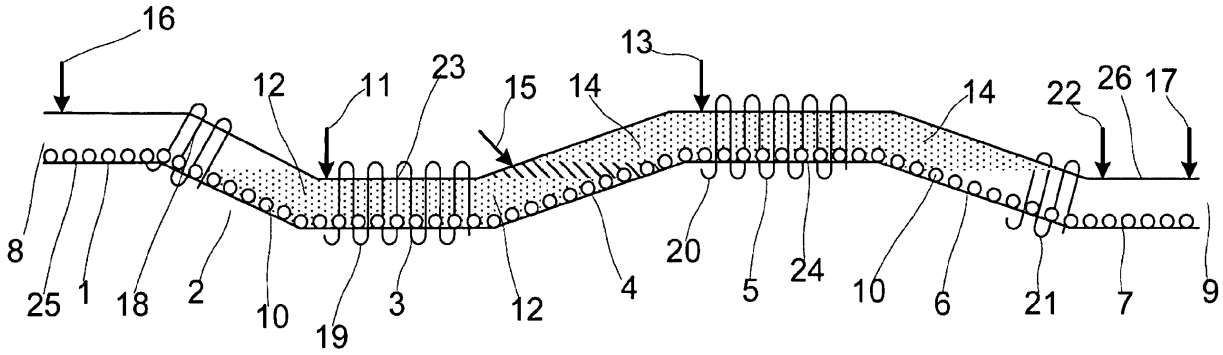
(54) **Continuous furnace**

(57) The invention relates to a continuous tunnel furnace for heat treatment of metal parts comprising at least a first and a second furnace section (3, 5) and means (11) to introduce a first gas into the first furnace section (3) and means (13) to introduce a second gas into the second furnace section (5), wherein the bottom plate of the second furnace section (5) is located above the cover plate of the first furnace section (3).

Fig. 1



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Description

[0001] The invention relates to a continuous tunnel furnace for heat treatment of metal parts which is confined by a bottom plate, side walls and a cover plate comprising an inlet section and an outlet section and means for conveying the metal parts through said tunnel furnace and comprising at least a first and a second furnace section and means to introduce a first gas into the first furnace section and means to introduce a second gas into the second furnace section. Further, the invention relates to a method for heat treatment of metal parts wherein said metal parts are conveyed through a first furnace section of a continuous tunnel furnace and then through a second furnace section of the continuous tunnel furnace, wherein said tunnel furnace is confined by a bottom plate, side walls and a cover plate.

[0002] European patent EP 1935508 B1 relates to a method for the modification of the surface structure of a metal body wherein in a first method stage the metal body is exposed to an oxidizing atmosphere and in a subsequent second method stage the metal body is exposed to a reducing atmosphere.

[0003] Continuous mesh belt furnaces with flat retort design exist with several zones but the gas consumption of these furnaces is high and the distinction from one zone to another is not very clear since the gas atmosphere from one zone will diffuse physically and thermodynamically into another zone.

[0004] In the process of EP 1935508 B1 the oxidising atmosphere and the reducing atmosphere shall be kept separate from each other and not being mixed. Therefore, in the state of the art the above mentioned process of first oxidising and then reducing the metal body is carried out in two distinct steps, i.e. in two separate furnaces or two separate furnace chambers.

[0005] It is already known to use so-called hump back furnaces for heat treatment of metal parts, especially for exposure of the metal parts to a hydrogen atmosphere. Such hump back furnaces comprise an inclined inlet passage, a heat treatment section and a declining outlet section. Hydrogen is a very light element and, therefore, in industrial furnaces not easy to handle. The hump-back furnaces are designed to address the weight issue. The light hydrogen will rise up to the heat treatment section at the top of the furnace.

[0006] However, hump back furnaces are not capable of implementing different zones with complex furnace atmosphere mixtures.

[0007] It is an object of the present invention to provide a continuous furnace and a respective method for exposing metal parts inline to two different heat treatment atmospheres.

[0008] This object is achieved by a continuous tunnel furnace for heat treatment of metal parts which is confined by a bottom plate, side walls and a cover plate and which comprises an inlet section and an outlet section and means for conveying the metal parts through said tunnel furnace and comprising at least a first and a second furnace section and means to introduce a first gas into the first furnace section and means to introduce a second gas into the second furnace section. The inventive tunnel furnace is **characterized in that** an inclining or declining passage is provided between said first furnace section and said second furnace section and in that the bottom plate of the second furnace section is located above the cover plate of the first furnace section.

[0009] The inventive method for heat treatment of metal parts wherein said metal parts are conveyed through a first furnace section of a continuous tunnel furnace and then through a second furnace section of the continuous tunnel furnace, wherein said tunnel furnace is confined by a bottom plate, side walls and a cover plate, is **characterized in that** the bottom plate of the second furnace section is located above the cover plate of the first furnace section.

[0010] The terms bottom plate, cover plate and side walls shall mean the lower, upper and lateral walls which form the tunnel. The bottom plate and/or the cover plate and/or each of the side walls can be formed as one piece or can be assembled or composed of several pieces.

[0011] The inventive continuous tunnel furnace comprises two furnace sections where the metal parts are exposed to different heat treatment atmospheres. In order to keep the gas atmospheres separate from each other, the first and the second furnace atmosphere are arranged at different heights: The bottom plate of the second furnace section is located above the cover plate of the first furnace section. The volume of the second furnace section is thus arranged above the highest point of the first furnace section.

[0012] The first and the second furnace section are open to each other, i.e. neither the first nor the second furnace section are provided with a door which could separate the volume of that furnace section from the remainder of the furnace. The furnace is a tunnel furnace without separations, partitions or doors between single furnace sections. The furnace is open such that gas could in principle flow through all furnace sections but due to the inventive furnace design heavier gas will stay in the first furnace section and lighter gas will stay in the second furnace section as will be explained below.

[0013] In the first furnace section the metal parts are heat treated with a heavy gas medium and in the second furnace section the metal parts are exposed to a light gas medium. The terms "heavy" and "light" are relative and shall mean that the heavy gas will sink to the bottom of the furnace and therefore collect in the low first furnace section. On the other hand, the light gas medium will rise up to the second furnace section located above the first furnace section. Thereby, the invention allows to have two different gas atmospheres in a continuous tunnel furnace. "Light" and "heavy" shall in particular relate to the weight of air, i.e. the light gas is preferably lighter than air, the heavy gas is preferably heavier than air.

[0014] The terms "first furnace section" and "second

furnace section" do not necessarily mean that the first furnace section is located upstream the second furnace section. The metal parts can be first conveyed through the first furnace section and subsequently through the second furnace section or first through the second furnace section and then through the first furnace section. The terms "first furnace section" and "second furnace section" do not necessarily indicate the order of these furnace sections in the transport direction of the metal parts.

[0015] In a preferred embodiment the cover plate of said first furnace section is located below the bottom plate of said inlet section or below the bottom plate of said outlet section. As described above, the relative heavy gas medium will sink down inside the furnace and collect in the first furnace section. If the first furnace section is arranged close to the inlet section of the furnace, it is preferred to have a declining passageway from the inlet section to the first furnace section. Thereby, the relative heavy gas medium is prevented to flow into the inlet section and to leave the furnace through the furnace inlet.

[0016] In the same manner it is preferred to have an inclining passageway from the first furnace section to the outlet section if the first furnace section is arranged close to the outlet section of the furnace in order to prevent the heavy gas from leaving the furnace through the furnace outlet.

[0017] The same applies to the arrangement of the second furnace section relative to the inlet and / or outlet section. It is advantageous to locate the bottom plate of the second furnace section above the cover plate of said outlet section if the second furnace section is neighbouring the outlet section. Or, if the second furnace section abuts the inlet section, it is preferred to locate the bottom plate of the second furnace section above the cover plate of said inlet section. In analogy to the above described accumulation of the heavy gas in the first furnace section, the light gas shall accumulate in the second furnace section without leaving the furnace.

[0018] According to a preferred embodiment the first furnace section is provided with means for introducing a gas comprising essentially nitrogen or argon. The first furnace section is the furnace section where the relative heavy gas will collect. Therefore, due to its weight nitrogen and/or argon are introduced into that furnace section. It is especially preferred to create an argon atmosphere in the first furnace section.

[0019] For example, in the first furnace section the metal parts can be subjected to an oxidizing atmosphere. In that case it is preferred to introduce wet nitrogen or wet argon, that means nitrogen or argon loaded with water vapour or even saturated with water vapour, into the first furnace section. The water vapour will react with the surface of the metal parts and cause oxidation of the metal surface.

[0020] The reaction process and the effectivity of the heat treatment process can be enhanced by heating up the first furnace section. The first furnace section can be provided with heating means, especially indirect heating means, for example electric heating means, which allow to heat up the gas atmosphere in the first furnace section to a preferred treatment temperature. It is also possible to provide cooling means for cooling the atmosphere and the metal parts in the first furnace section.

[0021] The second furnace section which is located above the first furnace section is preferably used for heat treatment of the metal parts with hydrogen which is a very light gas. The second furnace section is therefore provided with means for introducing a gas comprising essentially hydrogen.

[0022] In the second furnace section, a particular heat treatment of the metal parts shall be achieved. Therefore, it can be helpful or even necessary to provide heating means or cooling means to set and control the temperature in the second furnace section.

[0023] Since the inventive furnace is a continuous tunnel furnace and since the first and the second furnace section are arranged at different heights, the first and the second furnace section are connected to each other via an inclining or a declining passageway - depending on which furnace section is arranged upstream with respect to the transport direction of the metal parts.

[0024] In the transition zone between the first furnace section and the second furnace section the two gas atmospheres will mix to some degree. It has been found advantageous to provide a gas curtain in that transition zone. A gas is introduced or blown into the transition zone in order to prevent the gas atmosphere from the first furnace section to get into the second furnace section and vice versa to prevent the gas atmosphere of the second furnace section to flow down to the first furnace section.

[0025] That gas curtain is preferably created by introducing an inert gas, for example nitrogen or argon, into the transition zone. It is in particular preferred to introduce a gas of the same type that is also used in either the first or the second furnace section. For example, if in the first furnace section, argon or wet argon is used as at least part of the gas atmosphere, then it is preferred to use argon for the gas curtain between both furnace sections, too. But it is also possible to use another gas, for example nitrogen, even if that gas is not used in any other part of the furnace.

[0026] At the inlet and / or outlet section it is preferred to create gas curtain, especially by introducing an inert gas or hydrogen into the inlet or outlet section. That gas curtain shall prevent air from entering the furnace atmosphere.

[0027] It can further be advantageous to provide heating or cooling means in the inlet and / or outlet section of the furnace to bring the metal part to the desired temperature for the heat treatment process or to cool down the metal part after the heat treatment process in the furnace.

[0028] The inventive furnace is a continuous furnace which allows a continuous processing of the metal parts without interruption. The first and the second furnace sec-

tion are preferably open to each other without any door. Contrary to pusher furnaces, the metal parts can be continuously processed.

[0029] If the inventive concept with a first and a second furnace section at different heights is applied to a mesh belt furnace, the mesh belt will also be exposed to the different gas atmospheres in the first and the second furnace section. That means, the mesh belt will experience the same heat treatment as the metal parts do. Such an ongoing exposure to different gas atmospheres can result in a reduced lifetime of the mesh belt. Therefore, it is preferred to provide at least two separate conveyors for conveying the metal parts through the tunnel furnace.

[0030] Even more preferred, the invention is applied to roller type furnaces or roller hearth furnaces. In such a furnace the metal parts are conveyed through the furnace on rollers. The parts can be directly placed on the rollers or processed in baskets or trays which are transported on the rollers.

[0031] The invention is especially useful for producing a metal part with a porous surface as described in EP 1935508 B1. The metal parts are treated in a heat treatment atmosphere in order to deposit nonmetallic elements or compounds containing these and/or to remove them from the surface layer. By suitably selecting the composition of the heat treatment atmosphere and corresponding selection of the process parameters such as for example pressure and temperature it is possible in this way to bring about reactions between the components of the heat treatment atmosphere and the surface of the metal body in a controlled manner and to produce a defined surface layer.

[0032] In the first furnace section the metal surface is initially oxidized and subsequently it is reduced in the second furnace section. During the oxidation step an oxide layer forms on the metal surface in the known manner. In the second step the oxidized metal surface is exposed to a reducing atmosphere. During this treatment at least a part of the existing oxides is removed through reduction, wherein corresponding pores remain in the surface.

[0033] The inventive furnace and the inventive method can also be used to expose metal parts to a decarburizing atmosphere in the first furnace section and then to expose the metal parts to a bright annealing atmosphere in the second furnace section.

[0034] The invention as well as further details of the invention shall now be explained with reference to the attached schematic drawing.

[0035] Figure 1 shows an inventive tunnel furnace. The tunnel furnace comprises different sections, such as an inlet section 1, a declining section 2, a first furnace section 3, an inclining transition section 4, a second furnace section 5, another declining section 6 and an outlet section 7. The furnace is designed as a tunnel furnace comprising a bottom plate, side walls and a cover plate such that the furnace is essentially closed to the surrounding atmosphere except for the inlet opening 8 and the outlet opening 9.

[0036] The furnace is designed as a roller type furnace, i.e. the metal parts which shall be exposed to the heat treatment atmosphere within the furnace are conveyed through the furnace on rollers 10.

[0037] The inventive furnace comprises a first furnace section 3 where the metal parts are heat treated in a wet argon atmosphere. Argon gas is passed through a water bath to get argon loaded and especially saturated with water vapour, so called wet argon. The wet argon is introduced into the first furnace section 3 via argon inlet 11. Argon is a gas heavier than air and thus the wet argon will sink down and collect in the first furnace section 3 which is located below the inlet section 1 and below the second furnace section 5. Thus, an atmosphere 12 of wet argon will be created in the first furnace section 3 and in the lower portions of the abuting declining section 2 and the inclining transition section 4.

[0038] In the second furnace section 5 the metal parts shall be exposed to a reducing hydrogen atmosphere. Therefore, hydrogen is introduced into the second furnace section 5 via hydrogen inlet 13. Since hydrogen is a very light gas, it will collect in the second furnace section 5 and create a hydrogen atmosphere 14 which extends to the upper portions of the neighbouring transition section 4 and the declining section 6.

[0039] In order to confine the argon in the first furnace section 3 the cover plate 23 of the first furnace section 3 is placed below the bottom plates 24, 25 of the second furnace section 5 and the inlet section 1, respectively. In the same manner, the bottom plate 24 of the second furnace section 5 is located above the cover plates 23, 26 of the first furnace section 3 and the outlet section 7 in order to keep the hydrogen in the second furnace section 5.

[0040] In the transition section 4 an inert gas 15 is introduced into the furnace in order to create a gas curtain between the wet argon atmosphere 12 in the first furnace section 3 and the hydrogen atmosphere 14 in the second furnace section 5. It is preferred to create an argon gas curtain, i.e. to use argon as the inert gas 15. But it is also possible to introduce another inert gas, such as nitrogen, into the transition section 4.

[0041] At the inlet 8 and at the outlet 9 of the furnace hydrogen 16, 17 is used to produce a flame curtain across the width and height of the inlet opening 8 and the outlet opening 9 in order to minimize the ingress of air into the furnace.

[0042] The inventive furnace is further provided with heating and/or cooling means 18, 19, 20, 21 in the inlet section 1, the declining section 2, the first furnace section 3, the second furnace section 5, the declining section 6 and/or the outlet section 7. Furthermore, hydrogen may be introduced into the outlet section 7 via hydrogen inlet 22.

[0043] The metal parts to be heat treated are conveyed through the furnace by means of the rollers 10. In the inlet section 1 and in the declining section 2 the metal parts and the furnace atmosphere are preheated by

means of heater 18.

[0044] The preheated metal parts then enter the wet argon atmosphere 12 (wet argon bath 12) in the first furnace section 3. The temperature in the first furnace section 3 can be set and adjusted by means of heater 19. The wet argon atmosphere causes an oxidation of the surface of the metal parts.

[0045] Subsequently the metal parts are passed through transition section 4 into the second furnace section 5 where they are exposed to a hydrogen atmosphere 14. The argon curtain 15 in transition section 4 minimizes the infiltration of argon from the wet argon atmosphere 12 into the hydrogen atmosphere 14 and in particular the infiltration of hydrogen from the hydrogen atmosphere 14 into the wet argon atmosphere 12.

[0046] The temperature in the second furnace section 5 can be set or controlled by means of a heating unit 20. Hydrogen is a reducing gas and causes a reduction of the surface of the metal parts. By the combination of oxidation and reduction a porous structure is produced in the surface layer of the metal parts.

[0047] Finally, the metal parts are passed through the declining section 6 and are directly cooled by hydrogen gas 22 and/or indirectly cooled by cooler 21.

[0048] The inventive tunnel furnace allows to continuously pass the metal parts through the furnace and to expose them to two different atmospheres without excessive mixing of the atmospheres between the two sections 3, 5. Contrary to pusher furnaces, no doors are required between the furnace sections with different atmospheres. Both sections are provided with heating capabilities to set, control and adjust the temperature in the first and the second furnace section 3, 5 according to the process requirements.

[0049] The furnace combines a first furnace section 3 which is designed as a kind of soaking pit furnace and a second furnace section 5 which is designed like a hump back furnace. That design allows to keep the heavy argon in the first furnace section 3 and the light hydrogen in the second furnace section 5. Thus, the argon and hydrogen consumption is minimized.

[0050] As described above, the invention can advantageously be used to produce metal parts with a porous surface layer by subsequent oxidation and reduction. Another preferred field of application is the decarburization of metal parts in argon followed by bright annealing in hydrogen.

Claims

1. Continuous tunnel furnace for heat treatment of metal parts which is confined by a bottom plate, side walls and a cover plate comprising an inlet section (1) and an outlet section (7) and means (10) for conveying the metal parts through said tunnel furnace and comprising at least a first and a second furnace section (3, 5) and means (11) to introduce a first gas into the first furnace section (3) and means (13) to introduce a second gas into the second furnace section (5), **characterized in that** an inclining or declining passage (4) is provided between said first furnace section (3) and said second furnace section (5) and **in that** the bottom plate of the second furnace section (5) is located above the cover plate of the first furnace section (3).

2. Continuous tunnel furnace according to claim 1, **characterized in that** the cover plate of said first furnace section (3) is located below the bottom plate of said inlet section (1) or below the bottom plate of said outlet section (7).

3. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** the bottom plate of said second furnace section (5) is located above the cover plate of said outlet section (7) or above the cover plate of said inlet section (1).

4. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** said means (11) for introducing a first gas into said first furnace section (3) comprises a supply for nitrogen, argon, nitrogen loaded with water vapour and/or argon loaded with water vapour.

5. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** said means (13) for introducing a second gas into the second furnace section (5) are connected to a hydrogen supply.

6. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** means (15) are provided for creating a gas curtain, especially an inert gas curtain, between the first furnace section (3) and the second furnace section (5).

7. Continuous tunnel furnace according to claim 6, **characterized in that** said means (15) for creating a gas curtain comprise means for introducing argon or nitrogen into the furnace between the first furnace section (3) and the second furnace section (5).

8. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** said first furnace section (3) and / or said second furnace section (5) are provided with heating means (19, 20).

9. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** said inlet section (1) and / or said outlet section (7) are provided with means (16, 17) for creating a gas curtain, especially with means for creating a hydrogen curtain.

10. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** said means (10) for conveying the metal parts through the tunnel furnace comprise rollers.

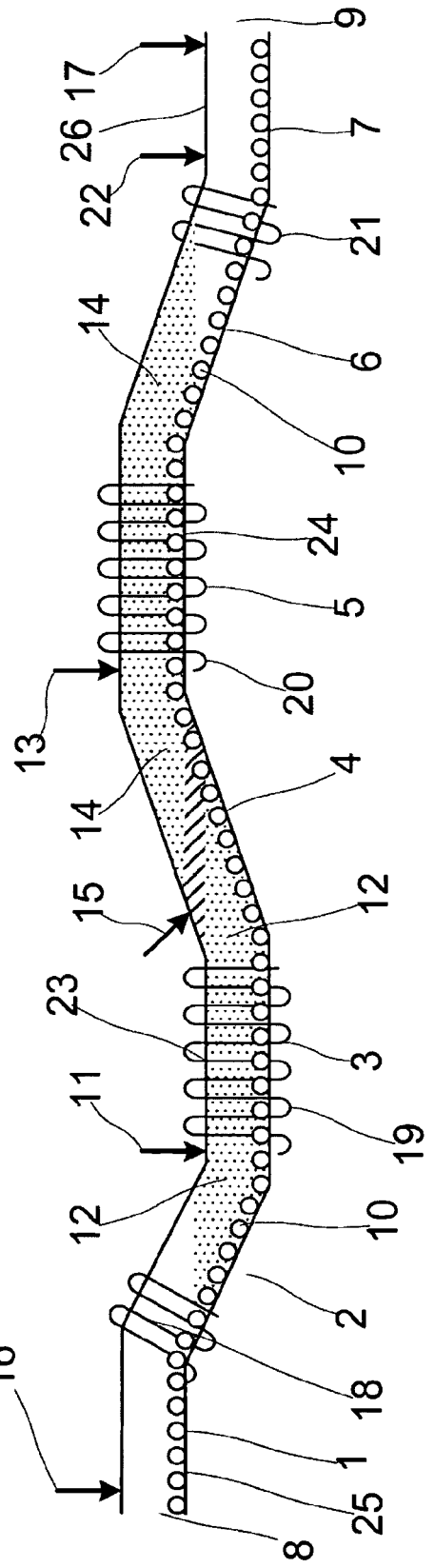
11. Continuous tunnel furnace according to any of the preceding claims, **characterized in that** said means for conveying the metal parts through the tunnel furnace comprise at least two separate conveyors.

12. Method for heat treatment of metal parts wherein said metal parts are conveyed through a first furnace section (3) of a continuous tunnel furnace and then through a second furnace section (5) of the continuous tunnel furnace, wherein said tunnel furnace is confined by a bottom plate, side walls and a cover plate, **characterized in that** the bottom plate of the second furnace section (5) is located above the cover plate of the first furnace section (3).

13. Method according to claim 12, **characterized in that** said metal parts are exposed to an oxidizing atmosphere (12) in said first furnace section (3) and **in that** said metal parts are exposed to a reducing atmosphere (14) in said second furnace section (5).

14. Method according to claim 12, **characterized in that** said metal parts are exposed to a decarburizing atmosphere in said first furnace section (3) and **in that** said metal parts are exposed to a bright annealing atmosphere in said second furnace section (5).

Fig. 1



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EUROPEAN SEARCH REPORT

Application Number
EP 12 00 5095

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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C21D
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F27D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	12 December 2012	Lilimpakis, Emmanuel

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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