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(54) **METHOD OF CONTROLLING AN ATMOSPHERE IN A FURNACE FOR PERFORMING SINTERING PROCESS**

(57) The present invention relates to a method of controlling an atmosphere in a furnace, particularly for performing a sintering process, wherein a dew point and/or a redox potential and/or a material concentration, particularly a mass fraction and/or a mole fraction and/or a volume concentration in the furnace is determined, wherein a base atmosphere comprising nitrogen and hydrogen is provided (201) in the furnace, wherein a fraction of hydrogen of the base atmosphere is predetermined (201) in dependence of a material to be sintered in the

furnace, wherein an additional amount of hydrogen is provided (203) in the furnace in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace, wherein an amount of a carbon potential enrichment gas and/or an amount of a carbon potential decreasing gas is provided (205) in the furnace in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace.

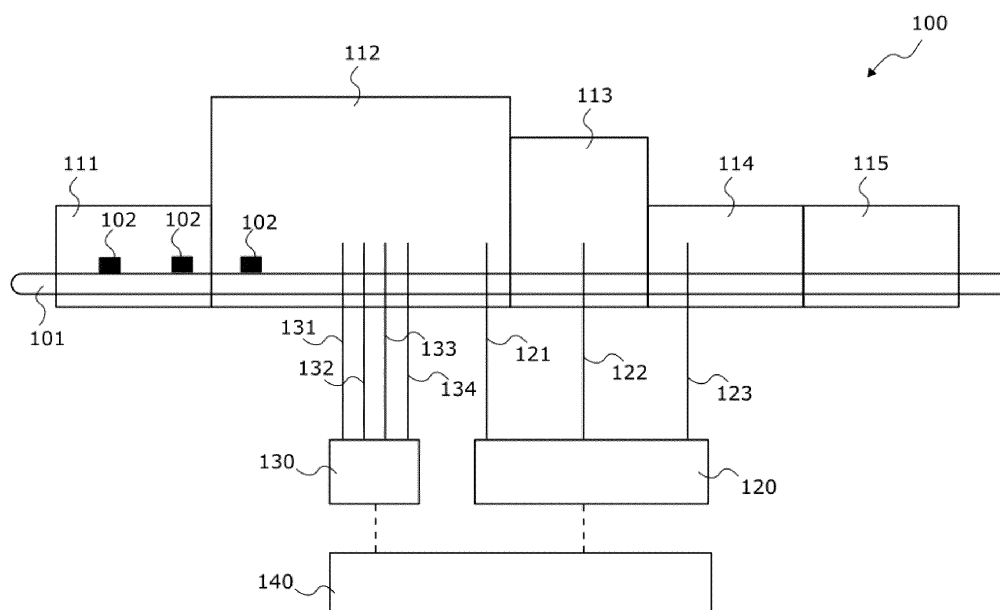


Fig. 1

Description

[0001] The present invention relates to a method of controlling an atmosphere in a furnace, particularly for performing a sintering process, a method of performing a sintering process and a furnace, particularly for performing a sintering process.

Prior art

[0002] Sintering is a process of compacting and forming a solid mass of material by heat or pressure without melting it to the point of liquefaction. Particularly, sintering is a thermal treatment of a powder or compact material at a temperature below the melting point of the main constituent of the material, for the purpose of increasing its strength by bonding of particles. During sintering atomic diffusion takes place and the particles are welded together.

[0003] The process of sintering can be performed in a furnace, in which a controlled protective atmosphere can be created in order to prevent oxidation and to promote the reduction of surface oxides as well as to control the carbon content to a desired level throughout the sintered objects. For this purpose, sintering atmospheres can contain nitrogen and hydrogen and sometimes hydrocarbons.

[0004] It is desirable to provide a possibility of effectively controlling an atmosphere in a furnace for performing a sintering process.

Disclosure of the invention

[0005] The present invention relates to a method of controlling an atmosphere in a furnace, particularly for performing a sintering process, a method of performing a sintering process and a furnace, particularly for performing a sintering process, with the features of the independent claims. Preferred embodiments and advantages of a method and a furnace according to the invention are subject of the dependent claims and arise from the following description.

[0006] In the present method a dew point and/or a redox potential and/or a material concentration in the furnace is determined. These values are particularly determined online during the operation of the furnace. The redox potential, also referred to as reduction potential or oxidation/reduction potential, is a measure of the tendency of a chemical species to acquire electrons and thereby be reduced. As a material concentration particularly a mass fraction and/or a mole fraction and/or a volume concentration can be determined, e.g. a corresponding material concentration of oxygen and/or hydrogen and/or carbon.

[0007] A base atmosphere comprising nitrogen and hydrogen is provided in the furnace. A fraction of hydrogen of the base atmosphere is predetermined in dependence of a material to be sintered in the furnace. A fraction

of nitrogen is particularly also predetermined in dependence of the material to be sintered. This predetermined hydrogen fraction is particularly a theoretical value which can be determined before performing the sintering process, i.e. before actual measurements of the dew point, the redox potential or the material concentration in the furnace.

[0008] An additional amount of hydrogen is provided in the furnace in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace. This amount of hydrogen is particularly determined online during the operation of the furnace.

[0009] Further, an amount of a carbon potential enrichment gas and/or an amount of a carbon potential decreasing gas is provided in the furnace in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace. Particularly, these amounts of the carbon potential enrichment gas and the carbon potential decreasing gas are also determined online during the operation of the furnace.

[0010] The base atmosphere is particularly predetermined according to a theoretical view of the furnace in order to provide optimum sintering quality and speed. However, this predetermined base atmosphere does not take into account the actual conditions inside the furnace which can vary and differ from the theoretical view. Therefore, in order to adapt the hydrogen/nitrogen atmosphere to the actual conditions inside the furnace the additional amount of hydrogen is provided. Thus, it can particularly be compensated for variations of the conditions inside the furnace and the base atmosphere can be adjusted such that optimum sintering quality and speed can be achieved.

[0011] Carbon potential is a measure of the capability of the furnace atmosphere to impart carbon into the material to be sintered. The carbon potential of an atmosphere can be defined as the carbon content of a thin sheet of pure iron in equilibrium with the atmosphere. By means of providing the carbon potential enrichment gas and/or the carbon potential decreasing gas the carbon potential of the furnace atmosphere can be adjusted, particularly in order to provide optimum sintering quality and speed.

[0012] The present method therefore provides a possibility to effectively control the atmosphere in the furnace for performing a sintering process. An atmosphere with specific properties for an optimum sintering process can be created in the furnace. An improved control of the furnace and the sintering process can thus be provided as well as an improved lifetime of the furnace components. Particularly, by adjusting the base atmosphere to the actual conditions in the furnace by means of the additional amount of hydrogen an optimisation of hydrogen consumption can be provided. Further, by adjusting the carbon potential by means of the carbon potential enrichment/decreasing gases effects of hydrogen in the carbon

potential can especially be compensated.

[0013] In order to determine the dew point, the redox potential and/or the material concentration corresponding sensors or measurement units can be provided in the furnace. Particularly, a gas sample or atmosphere sample can be removed from the furnace and analysed. For this purpose, the so called SINTERFLEX technology developed and distributed by the applicant can preferably be used. A gas sample from the furnace is for this purpose particularly passed through an external, heated SINTERFLEX probe designed for the sintering process and then through a carbon monoxide gas analyser. The results can be used to calculate e.g. the carbon potential of the furnace atmosphere. The system particularly uses a closed loop, constantly comparing gas measurements against the carbon potential to identify deviations.

[0014] Advantageously, the dew point and/or the redox potential and/or the material concentration is determined in an end of a heating zone and/or in a carbon restoration zone and/or in a precooling zone of the furnace. The furnace particularly comprises a preheating zone or delubrication zone, a heating or sintering zone, a carbon restoration zone, a precooling zone, and a cooling zone. The material to be sintered is particularly transported consecutively through the different zones of the furnace e.g. on a conveyer belt.

[0015] According to a preferred embodiment the fraction of hydrogen of the base atmosphere is predetermined in dependence of alloy factors of an alloy to be sintered in furnace, particularly such that iron and alloy oxides are removed from the material to be sintered in the furnace. The composition of the base atmosphere thus depends on the specific properties of the material to be sintered and is particularly predetermined such that an optimum sintering process can be performed.

[0016] Preferably, the fraction of hydrogen of the base atmosphere is predetermined in the range between 1% and 10%, more preferably between 2% and 8%, more preferably between 3% and 6%. The fraction of hydrogen can especially be predetermined in dependence of the condition of the furnace. For example in a new or clean or refurbished furnace or in a furnace with a new conveyor belt a hydrogen fraction of 3% can be predetermined. In an old or sooted or potentially leaky furnace a hydrogen fraction of e.g. 6% can be predetermined.

[0017] Advantageously, the additional amount of hydrogen is provided such that a predetermined value of the dew point and/or a predetermined value of the redox potential and/or a predetermined value of the material concentration is reached and particularly maintained in the furnace. By providing the additional amount of hydrogen the atmosphere in the furnace is thus particularly set up to a desired reducing potential and to provide a desired sintering quality and speed. Particularly, when the corresponding predetermined value is reached the additional amount of hydrogen is kept constant and the carbon potential enrichment/decreasing gas is added in order to control the carbon potential in the furnace.

[0018] Preferably, the additional amount of hydrogen is provided such that the dew point reaches a predetermined value below -40eC, more preferably below -45eC, more preferably between -45eC and -60eC. The additional amount of hydrogen is thus preferably controlled based on the actual dew point in the furnace.

[0019] Alternatively or additionally the additional amount of hydrogen is advantageously provided such that the redox potential reaches a predetermined value between 1200mV and 1400mV, preferably between 1250mV and 1350mV. Particularly, after the dew point reaches the corresponding predetermined value the additional amount of hydrogen is further provided such that also the redox potential reaches the corresponding predetermined value.

[0020] Advantageously the carbon potential enrichment gas and/or the carbon potential decreasing gas is provided such that a predetermined value of the dew point and/or a predetermined value of the redox potential and/or a predetermined value of the material concentration is reached and preferably maintained in the furnace. These predetermined values can be identical to or can differ from the above referenced predetermined values which are reached by providing the additional amount of hydrogen. It is particularly possible that by providing the additional amount of hydrogen first predetermined values are reached and by providing the carbon potential enrichment/decreasing gas second predetermined values are reached.

[0021] According to a preferred embodiment, at least two values for the amount of the carbon potential enrichment gas and/or the carbon decreasing gas are determined in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace. Particularly, one value can be determined in dependence of the determined dew point and one value in dependence of the determined redox potential. An average value of these at least two values is preferably determined and the carbon potential enrichment gas and/or the carbon decreasing gas is preferably provided according to the determined average value.

[0022] Preferably, the carbon potential enrichment gas and/or the carbon potential decreasing gas is provided such that the redox potential reaches a value between 1200mV and 1500mV, more preferably between 1250mV and 1400 mV, more preferably between 1350mV and 1450mV.

[0023] Advantageously, the predetermined value of the dew point and/or the predetermined value of the redox potential and/or the predetermined value of the material concentration is predetermined in dependence of an amount of carbon of the material to be sintered in the furnace. For example for an amount of carbon larger than 0.7% a redox potential of 1450mV can be predetermined. For a carbon amount smaller than 0.7% a redox potential e.g. between 1350mV and 1450mV can be predetermined.

[0024] For an amount of carbon of the material to be sintered below 0.6% the predetermined value of the redox potential is preferably below 1400mV. For a material to be sintered with a carbon amount between 0.6% and 0.9% the predetermined value of the redox potential is advantageously between 1350mV and 1450mV. The predetermined value of the redox potential is preferably above 1450mV for an amount of carbon of the material to be sintered above 0.9%.

[0025] Advantageously, methane CH_4 and/or propane C_3H_8 and/or liquid petroleum gas LPG and/or a hydrocarbon gas is provided as the carbon potential enrichment gas. As the carbon potential decreasing gas advantageously carbon dioxide CO_2 and/or nitrogen dioxide NO_2 and/or oxygen O_2 , pure or in air, and/or air is provided.

[0026] The present invention further relates to a method for performing a sintering process, wherein an atmosphere is created and controlled in a furnace according to a method according to the above description and wherein a sintering process of a material is performed in the furnace. Particularly, after the atmosphere is created and controlled in the furnace the material to be sintered is provided to the furnace and especially transported through the furnace and its various zones e.g. on a conveyor belt. In the furnace the sintering process of the material is performed, i.e. a thermal treatment of the material at a temperature below the melting point of its main constituent particularly in order to increase its strength by bonding of the particles.

[0027] The invention further relates to a furnace particularly for performing a sintering process adapted to be controlled according to a method according to the above description. Advantages and preferred embodiments of the method and the furnace according to the present invention arise from the above description in an analogous manner.

[0028] It should be noted that the previously mentioned features and the features to be further described in the following are usable not only in the respectively indicated combination, but also in further combinations or taken alone, without departing from the scope of the present invention.

[0029] The present invention will now be described further, by way of example, with reference to the accompanying drawings, in which

Figure 1 schematically shows a preferred embodiment of a furnace according to the present invention adapted to be controlled according to a preferred embodiment of a method according to the present invention, and

Figure 2 schematically shows a preferred embodiment of a method according to the present invention as a block diagram.

Detailed description

[0030] A preferred embodiment of a furnace 100 according to the present invention for performing a sintering process is schematically shown in Figure 1.

[0031] The furnace 100 comprises different zones, e.g. a preheating zone 111 or delubrication zone 111, a heating zone 112 or sintering zone 112, a carbon restoration zone 113, a precooling zone 114 and a cooling zone 115. Objects 102 to be sintered are transported through these different zones on a conveyer belt 101.

[0032] Further, a measurement unit 120 to determine a dew point, a redox potential and a material concentration in different locations in the furnace 100 is provided, namely in an end of the heating zone 112, in the carbon restoration zone 113 and in the precooling zone 114. For this purpose gas samples can be removed from the heating zone 112 via a pipe 121, from the carbon restoration zone 113 via a pipe 122 and from the precooling zone 114 via a pipe 123. The removed gas samples can be analysed in the measurement unit 120. The pipes 121, 122, 123 and the measurement unit 120 can particularly be part of a so called SINTER FLEX system.

[0033] A gas unit 130 is adapted to provide certain amounts of different gases to the furnace. For example via a first gas lance 131 nitrogen can be provided, via a second gas lance 132 hydrogen can be provided, via a third gas lance 133 a carbon potential enrichment gas like methane or propane can be provided, and via a fourth gas lance 134 a carbon potential decreasing gas like carbon dioxide can be provided.

[0034] Although it is schematically shown in Fig. 1 that the gas lances 131, 132, 133, 134 provide the corresponding gases to the heating zone 112, it is also possible that the corresponding gases are alternatively or additionally provided also at other locations in the furnace 100. It is particularly possible that different gases can be provided at different locations in the furnace 100.

[0035] A control unit 140 is provided and adapted to communicate with and control the measurement unit 120 and the gas unit 130. The control unit 140 is particularly adapted to control the atmosphere in the furnace. For this purpose the control unit 140 is particularly adapted to perform a preferred embodiment of a method according to the present invention, as will now be explained with reference to Figure 2.

[0036] In Figure 2 a preferred embodiment of the method according to the invention is schematically shown as a block diagram.

[0037] In step 201 a fraction of hydrogen and nitrogen of a base atmosphere is predetermined in dependence of a material of the objects 102 to be sintered in the furnace 100. Particularly, the fractions of hydrogen and nitrogen are predetermined based on alloy factors of an alloy to be sintered, such that iron and alloy oxides are removed from the material to be sintered.

[0038] In step 202 the base atmosphere comprising nitrogen and hydrogen with the predetermined fractions

of step 201 is provided in the furnace 100 by means of the gas unit 130.

[0039] In step 203 an additional amount of hydrogen is provided by means of the gas unit 130 in dependence of the dew point and the redox potential determined by the measurement unit 120. This additional amount of hydrogen is particularly provided such that the dew point reaches a first predetermined value of e.g. below -40eC and e.g. that the redox potential reaches a first predetermined value of at least 1250mV.

[0040] In step 204 it is therefore evaluated whether the dew point has reached the first predetermined value of below -40eC and whether the redox potential has reached the first predetermined value of at least 1250mV.

[0041] If this is the case, in step 205 an amount of the carbon potential enrichment gas and/or an amount of the carbon potential decreasing gas is provided by means of the gas unit 130 in dependence of the redox potential determined by the measurement unit 120. Particularly, the carbon potential enrichment gas and the carbon potential decreasing gas are provided such that the redox potential reaches and maintains a second predetermined value which depends on the amount of carbon of the material of the objects 102 to be sintered. For example, this second predetermined value can be in the range between 1350mV and 1450mV.

[0042] In step 206 it is thus evaluated whether the redox potential has reached this second predetermined value. If this is the case, in step 207 the conveyor belt 101 is started and the sintering process of the objects 102 in the furnace 100 is performed.

[0043] In the following three examples will be given of different amounts of gases and different predetermined values to create different atmospheres in the furnace according to preferred embodiments of the present invention.

1st Example

[0044] In step 201 it is predetermined that the fraction of hydrogen of the base atmosphere is 3% and that the fraction of nitrogen is thus 97%. This base atmosphere is provided in step 202.

[0045] In step 203 the additional amount of hydrogen is provided such that the dew point reaches a first predetermined value between -45eC and -60eC.

[0046] In step 204 it is evaluated whether the dew point reaches this first predetermined value and whether the redox potential reaches a first predetermined value of 1250mV and/or whether a material concentration of hydrogen is below 20%

[0047] If this is case in step 205 methane CH₄ is provided used as carbon potential enrichment gas and carbon dioxide CO₂ is provided as carbon potential decreasing gas such that the redox potential reaches a second predetermined value between 1250mV and 1400mV and such that the dew point maintains the first predetermined value below -45eC.

[0048] According to this first example an atmosphere can be created in the furnace 100 such that a lifetime of the conveyor belt 101 can be maximised.

5 2nd Example

[0049] According to a second example in step 201 the hydrogen fraction of the base atmosphere is predetermined between 3% and 6% and the nitrogen fraction is thus predetermined between 97% and 94% depending on the condition of the furnace 100.

[0050] For new or refurbished or clean furnaces 100 or for furnaces 100 with new conveyor belts 101 a hydrogen fraction of 3% is e.g. predetermined. For an old or highly sooted or potentially leaky furnace 100 a hydrogen fraction of 6% is e.g. predetermined.

[0051] This base atmosphere is provided in step 202 and in step 203 the additional amount of hydrogen is provided such that the dew point in the hot zone 112 of the furnace 100 reaches a first predetermined value between -45eC.

[0052] In step 204 it is evaluated whether the dew point has reached this first predetermined value between -45eC and whether the redox potential has reached a first predetermined value of 1350mV and whether the hydrogen concentration is below 15%.

[0053] If this is the case methane CH₄ is provided in step 205 as carbon potential enrichment gas such that the redox potential reaches a second predetermined value depending on the amount of carbon of the objects 102 to be sintered. For an amount of carbon above 0.7% a second predetermined value of e.g. at least 1450mV is used and for a carbon amount below 0.7% a second predetermined value between 1350mV and 1450mV is e.g. used.

[0054] With the atmosphere according to this second example optimised hydrogen consumption can be provided.

40 3rd Example

[0055] According to a third example steps 201 to 204 are performed analogously to the second example. In step 205 propane C₃H₈ or methane CH₄ is provided as carbon potential enrichment gas such that the redox potential reaches a second predetermined value depending on the amount of carbon of the objects 102 to be sintered.

[0056] For alloys with a carbon amount below 0.6% the second predetermined value of the redox potential is at most 1400mV. For alloys between 0.6% and 0.9% carbon the second predetermined value of the redox potential is between 1350mV and 1450mV. For alloys over 0.9% carbon content the second predetermined value of the redox potential is at least 1450mV.

[0057] With the atmosphere of this third example, the carbon potential in the furnace 100 can be optimised and controlled.

Claims

1. Method of controlling an atmosphere in a furnace (100), particularly for performing a sintering process, wherein a dew point and/or a redox potential and/or a material concentration, particularly a mass fraction and/or a mole fraction and/or a volume concentration in the furnace (100) is determined, wherein a base atmosphere comprising nitrogen and hydrogen is provided (201) in the furnace, wherein a fraction of hydrogen of the base atmosphere is predetermined (201) in dependence of a material (102) to be sintered in the furnace (100), wherein an additional amount of hydrogen is provided (203) in the furnace (100) in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace (100), wherein an amount of a carbon potential enrichment gas and/or an amount of a carbon potential decreasing gas is provided (205) in the furnace (100) in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace (100). 5
2. The method according to claim 1, wherein the dew point and/or the redox potential and/or the material concentration is determined in an end of a heating zone (112) and/or in a carbon restoration zone (213) and/or in a precooling zone (214) of the furnace (100). 10
3. The method according to claim 1 or 2, wherein the fraction of hydrogen of the base atmosphere is predetermined (201) in dependence of alloy factors of an alloy (102) to be sintered in furnace (100), particularly such that iron and alloy oxides are removed from the material (102) to be sintered in the furnace (100). 15
4. The method according to any one of the preceding claims, wherein the fraction of hydrogen of the base atmosphere is predetermined (201) in the range between 1% and 10%, particularly between 2% and 8%, particularly between 3% and 6%. 20
5. The method according to any one of the preceding claims, wherein the additional amount of hydrogen is provided (203) such that a predetermined value of the dew point and/or a predetermined value of the redox potential and/or a predetermined value of the material concentration is reached (204) in the furnace (100). 25
6. The method according to claim 5, wherein the additional amount of hydrogen is provided (203) such that the dew point reaches (204) a predetermined value below -40°C, particularly below -45°C, particularly 30
7. The method according to any one of the preceding claims, wherein the carbon potential enrichment gas and/or the carbon potential decreasing gas is provided (205) such that a predetermined value of the dew point and/or a predetermined value of the redox potential and/or a predetermined value of the material concentration is reached (206) in the furnace (100). 35
8. The method according to claim 7, wherein at least two values for the amount of the carbon potential enrichment gas and/or the carbon decreasing gas are determined in dependence of the determined dew point and/or the determined redox potential and/or the determined material concentration in the furnace (100), wherein an average value of these at least two values is determined and wherein the carbon potential enrichment gas and/or the carbon decreasing gas is provided according to the determined average value. 40
9. The method according to claim 7 or 8, wherein the carbon potential enrichment gas and/or the carbon potential decreasing gas is provided (205) such that the redox potential reaches (206) a value between 1200mV and 1500mV, particularly between 1250mV and 1400 mV, particularly between 1350mV and 1450mV. 45
10. The method according to any one of the claims 7 to 9, wherein the predetermined value of the dew point and/or the predetermined value of the redox potential and/or the predetermined value of the material concentration is predetermined (205) in dependence of an amount of carbon of the material (102) to be sintered in the furnace (100). 50
11. The method according to claim 10, wherein for an amount of carbon of the material (102) to be sintered below 0.6% the predetermined value of the redox potential is below 1400mV, for an amount of carbon of the material (102) to be sintered between 0.6% and 0.9% the predetermined value of the redox potential is between 1350mV and 1450mV, for an amount of carbon of the material (102) to be sintered above 0.9% the predetermined value of the redox potential is above 1450mV. 55
12. The method according to any one of the preceding claims, wherein methane and/or propane and/or liquid petroleum gas and/or a hydrocarbon gas is provided (205) as the carbon potential enrichment gas.

13. The method according to any one of the preceding claims, wherein carbon dioxide and/or nitrogen dioxide and/or oxygen and/or air is provided (205) as the carbon potential decreasing gas. 5
14. Method for performing a sintering process, wherein an atmosphere is created and controlled (201, 202, 203, 204, 205, 206) in a furnace (100) according to a method according to any one of the preceding claims, 10 wherein a sintering process of a material (102) is performed (207) in the furnace (100).
15. A furnace (100) particularly for performing a sintering process adapted to be controlled according to a method according to any one of claims 1 to 14. 15

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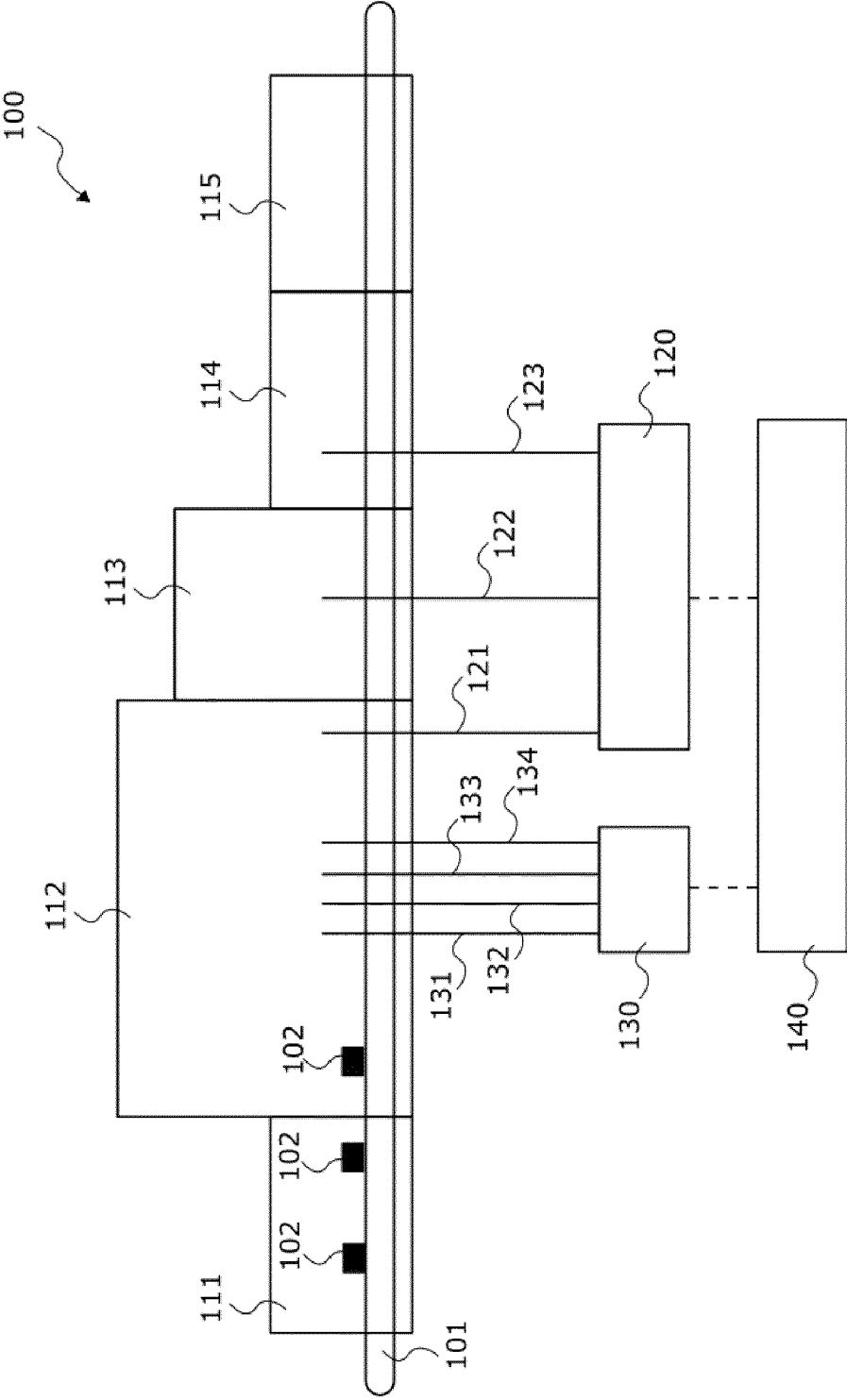


Fig. 1

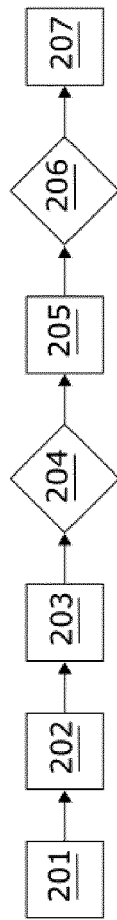


Fig. 2



EUROPEAN SEARCH REPORT

Application Number
EP 18 02 0414

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 29 January 2019	Examiner Jung, Régis
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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