In a method for determining a dividedness and/or position of a batch material (7) existing essentially in the solid phase in an arc furnace (1) having a furnace vessel (2), acoustic signals $N_s, N_g, N_d$ are generated by an arc discharge $6$ between an electrode $3a, 3b, 3c$ and the batch material (7). The acoustic signals $N_s, N_g, N_d$ reflected and/or transmitted through by the batch material (7) are measured by acoustic sensors $5a, 5b, 5c, 5e, 5g, 5h, 5s, 5r$, wherein at least one acoustic sensor $5a, 5b, 5c, 5e, 5g, 5h, 5s, 5r$ is provided per segment $S_s$ of the furnace vessel (2) subdivided into a plurality of segments $S_s$, and wherein the dividedness and/or position of the batch material (7) in the arc furnace (1) is determined by evaluating the measured acoustic signals $N_s, N_g, N_d$. 

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METHOD FOR DETERMINING THE PROPERTIES OF THE CONTENT OF AN ARC FURNACE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a U.S. national stage application of International Application No. PCT/EP2006/063643 filed Jun. 28, 2006, which designates the United States of America, and claims priority to German application number 10 2005 034 378.3 filed Jul. 22, 2005, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] The invention relates to a method for determining the status of the content of an arc furnace for melting a batch material.

BACKGROUND

[0003] A batch material, for example scrap metal, is melted in an arc furnace by supplying energy. In an electric arc furnace for producing steel, for example, energy is supplied to the batch material by forming an arc discharge with the aid of electrodes. Chemical energy is in this case preferably also put in using additional combustible materials which, for example, at least partially comprise coal and/or oxygen.

[0004] The process taking place in the arc furnace depends essentially on the status of the content of the electric arc furnace. It is known to sort and classify scrap metal, and to supply scrap metal to the electric arc furnace in a sorted fashion while following a loading plan. Conclusions can then be made regarding the state inside the furnace based on the scrap metal sorting and based on the loading plan, although these suffer from a comparatively high level of uncertainty and susceptibility to error.

SUMMARY

[0005] According to an embodiment, a method for determining a dividedness and/or position of a batch material existing essentially in the solid phase in an arc furnace having a furnace vessel, may comprise the steps of: generating acoustic signals by an arc discharge between an electrode and the batch material, and measuring the acoustic signals reflected and/or transmitted through by the batch material by means of acoustic sensors, wherein at least one acoustic sensor is provided per segment of the furnace vessel subdivided into a plurality of segments, and wherein the dividedness and/or position of the batch material in the arc furnace is determined by evaluating the measured acoustic signals.

[0006] According to another embodiment, a device for determining a dividedness and/or position of a batch material existing essentially in the solid phase in an arc furnace having a furnace vessel, may comprise: means for generating acoustic signals by an arc discharge between an electrode and the batch material, and acoustic sensors for measuring the acoustic signals reflected and/or transmitted through by the batch material, wherein at least one acoustic sensor is provided per segment of the furnace vessel subdivided into a plurality of segments, and wherein the dividedness and/or position of the batch material in the arc furnace is determined by evaluating the measured acoustic signals.

[0007] According to a further embodiment, at least one acoustic sensor, which is arranged on the furnace vessel and/or on other parts of the arc furnace, can be used for measuring the acoustic signals. According to a further embodiment, electrical signals can be additionally measured with the aid of at least one electrical sensor in order to determine the dividedness and/or position in the arc furnace. According to a further embodiment, electrical signals can be measured between at least two electrodes of the arc furnace by means of an electrical sensor. According to a further embodiment, measurement values and data obtained from the measurement values can be stored in a database for early detection of a collapse of the batch material. According to a further embodiment, measurement values and data obtained from the measurement values can be compared with measurement values and with data which are stored in the database. According to a further embodiment, the method may further comprise the step of: using the determined dividedness and/or position of the batch material of the arc furnace for controlling or regulating the arc furnace. According to a further embodiment, in order to avoid breakage of one or more of the electrodes, the energy supply to the electrodes can be regulated. According to a further embodiment, the position of the electrodes can be regulated. According to a further embodiment, the arc furnace may be deliberately operated asymmetrically. According to a further embodiment, the supply of chemical energy into the arc furnace can be regulated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Further advantages and details of the invention will be described below with the aid of examples in conjunction with the drawings, in which:

[0009] FIG. 1 schematically shows an arc furnace coupled to a computing device and having a furnace vessel,

[0010] FIG. 2 shows the furnace vessel in a schematic representation,

[0011] FIG. 3 shows a segment of the furnace vessel,

[0012] FIG. 4 schematically shows an example of the propagation of acoustic signals in the furnace vessel.

DETAILED DESCRIPTION

[0013] According to an embodiment, in a method for determining the status of the content of an arc furnace, in particular an electric arc furnace, acoustic signals from the arc furnace are measured. In this way, and particularly by evaluating the measured acoustic signals, the status of the content of the arc furnace, in particular of the electric arc furnace, can be determined substantially more accurately and reliably. By the improved method according to an embodiment for determining the status of the content of an arc furnace, the energy input into the arc furnace, in particular an electric arc furnace, can be better regulated locally and quantitatively.

[0014] At least one acoustic sensor which may be arranged on the furnace vessel and/or on other parts of the arc furnace, in particular the electric arc furnace, can be advantageously used for measuring the acoustic signals.

[0015] Advantageously electrical signals, in particular current, voltage and/or energy, can be additionally measured with the aid of at least one electrical sensor in order to determine the status of the content of the arc furnace, in particular the electric arc furnace. Substantially more accurate information regarding the status of the content of the arc furnace can be obtained in this way, in particular by combined evaluation of the measurement data obtained both from acoustic measurement and from electrical measurement.
[0016] Electrical signals, in particular current, voltage and/or energy, can be advantageously measured between at least two electrodes of the arc furnace by means of an electrical sensor.

[0017] The status of the batch material, which advantageously consists at least partially of scrap metal, may be advantageously determined.

[0018] Measurement values and/or data obtained from the measurement values may be advantageously stored in a database for early detection of collapses of the batch material.

[0019] Instantaneous measurement values and/or data obtained from the measurement values may be advantageously compared with measurement values and/or with corresponding data which are stored in the database.

[0020] A status of the content of the arc furnace, which with a high likelihood will lead to a collapse of the batch material and/or to damage at the electrodes, can thereby be detected particularly promptly. It is therefore possible to counteract such events in time.

[0021] In the method for operating an arc furnace, wherein information about the status of the content of the arc furnace, which has been determined with the aid of a method as described above, the information can be used for controlling or regulating the arc furnace.

[0022] The energy supply to the electrodes may be advantageously regulated in order to avoid breaking of one or more of the electrodes.

[0023] The position of the electrodes can be advantageously regulated.

[0024] Advantageously, the arc furnace can be deliberately operated asymmetrically, i.e., the position of the electrodes and/or the energy supply to the electrodes is at least temporarily set non-symmetrically.

[0025] The supply of chemical energy into the arc furnace can be advantageously regulated.

[0026] According to another embodiment, a device may have means suitable for carrying out a method as described above, the device comprising an arc furnace with acoustic sensors.

[0027] FIG. 1 shows an arc furnace 1, which is designed as an electric arc furnace in the exemplary embodiment. The arc furnace 1 comprises a plurality of electrodes, three electrodes 3a, 3b, 3c; in the example shown, which preferably are arranged so that their position can be modified and which extend at least partially into the furnace vessel 2 of the electric arc furnace.

[0028] Electrical current can preferably flow between the electrodes 3a, 3b, 3c and/or between the electrodes 3a, 3b, 3c- and the furnace container 2. Owing to this, an electric arc discharge 6 is formed in the furnace vessel 2. The arc discharge 6 is indicated merely symbolically in the drawing. In order to measure electrical signals ES, for example in order to measure the current between the electrodes 3a, 3b, 3c, an electrical sensor 4a is provided. Acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t, with the aid of which acoustic signals Ss, Ns, Ng (see FIG. 4) from inside the arc furnace 1 can be recorded, are arranged around the arc furnace 1. Measurement data of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t are delivered to suitable evaluation means 11. Optionally, measurement data of the at least one electrical sensor 4a is also delivered to the suitable evaluation means 11.

[0029] The acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t are arranged around the furnace vessel 2 in the example shown. Acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t may be arranged not only on the furnace vessel 2 but also, as an alternative or in addition, for example on a cover (not represented in detail) of the arc furnace 1. Acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t may, for example, be arranged so that they are connected indirectly and/or directly to the furnace vessel 2 and/or to the arc furnace 1.

[0030] It is, however, particularly advantageous to arrange the acoustic sensor 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t directly on the furnace container 2 and/or on the cover (not represented in detail) of the arc furnace 1.

[0031] A computing device 10 is advantageously provided, to which the arc furnace 1 is coupled. The computing device 10 sends control signals CS to the arc furnace, for example in order to influence the position of the electrodes 3a, 3b, 3c and/or the energy supply to the electrodes 3a, 3b, 3c. To this end, the computing device 10 comprises a control module 12. The computing device 10 preferably comprises evaluation means 11 with the aid of which measurement data, which are communicated from the plurality of acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t and/or the at least one electrical sensor 4a, are optionally processed and analyzed. A structure-borne noise analysis is carried out by evaluating the signals of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t.

[0032] As schematically represented in FIG. 2, the furnace vessel 2 may be subdivided into one or more segments Ss with an angle αs. The segments Ss preferably have a uniform angle αs. In an alternative configuration, the angle αs may differ from segment Sa to segment Ss. It is, for example, possible to divide the furnace vessel 2 into segments Ss so that the segments Ss are arranged at least approximately with point symmetry. Preferably, at least one acoustic sensor 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t is provided per segment Ss. In an exemplary configuration according to an embodiment, it is possible for no acoustic sensor 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t to be provided in one or more segments Ss. According to an embodiment, however, at least one acoustic sensor 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t is provided. Preferably, at least two acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t are provided.

[0033] As schematically indicated in FIG. 3, a segment Sa with an angle αs may be further decomposed into a horizontal segments hsa, hsb, ..., hsp and/or vertical segments vsa, vsb, ..., vsz, in order to establish the arrangement of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5s, 5t.

[0034] FIG. 4 schematically shows a detail of an arc furnace 1, and in particular the content of the furnace vessel 2 and the electrode 3a are represented merely schematically. The furnace vessel 2 contains the batch material 7, in particular scrap metal, which is melted with the aid of at least one electrode 3a to form a melt 8, in particular liquid steel. The batch material 7 is melted in particular by supplying energy to the interior of the arc furnace 1 by the action of the arc discharge 6 (represented merely schematically), which is formed in particular between the electrode 3a and the batch material 7 or the melt 8. Slag 9 may be formed above the melt 8 inside the arc furnace 1.

[0035] The batch material 7 is formed by a plurality of pieces, and preferably exists essentially in the solid phase. The status of the content of the arc furnace 1, in particular the status of the batch material 7, is characterized above all by the dividedness of the batch material 7. The dividedness of the batch material 1 is characterized for example by length, width, height, position, shape, weight and/or density of the batch material 7, or of the pieces forming the batch material 7. The dividedness and in particular the position of the batch
material 7, in particular scrap metal, influences the input of energy into the arc furnace 1. Said features, or the characteristics of the batch material 7, i.e. the status of the content of the arc furnace 1, may cause scrap metal collapses which can lead to electrode breakages and therefore to shutdown of the arc furnace 1. The input of energy into the arc furnace 1 varies owing to inhomogeneity and/or inconsistency of the batch material 7, for which reason the performance capacity of one or more furnace transformers (not represented in detail in the drawings), which are coupled to the electrodes 3a, 3b, 3c, cannot fully be utilized. According to an embodiment, it is possible to substantially avoid collapses of the batch material 7, electrode breakages and furnace shutdowns.

By suitable regulation, the performance capacity of one or more furnace transformers can be utilized better. To this end a plurality of acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, only a few of which are represented by way of example in FIGS. 1 and 4, are preferably arranged on the furnace vessel 2, in particular on the wall of the furnace vessel 2. For structure-borne noise measurement, the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r are arranged at suitable measurement positions around the furnace, and optionally also on the furnace cover. With the aid of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, a structure-borne noise analysis can be carried out. At the same time available current signals, i.e. electrical signals ES (see FIG. 1), are processed and analyzed by suitable measurement methods. With the aid of the evaluation means 11 represented in FIG. 1, the signals available from both measurement methods (electrical and acoustic measurement) are preferably processed with the aid of one or more algorithms in the form of a hybrid system to obtain evaluation data.

The acoustic signals Np, Ne, Ns are generated in particular in the electrical discharge between the electrode and the batch material 7 or melt 8. Some of the acoustic signals Np, Ns, Ne are reflected by the batch material 7, in particular scrap metal. This gives rise to reflected acoustic signals Np. Acoustic signals are transmitted through the batch material 7 and/or reflected by it. Both may possibly take place repeatedly and in a different way for various acoustic signals Np, Ns, Ne. The acoustic signals are transmitted further at the wall (sidewalls, panels and also cover) of the furnace vessel 2, in particular through the solid body of the batch material 7.

By correlating the measurement data obtained with the aid of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, it is possible to obtain information about the density of the batch material 7, and in particular it is possible to determine for example the positions at which the highest or lowest scrap metal density exists. By evaluating the measurement data obtained with the aid of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, information can be obtained regarding the density and/or position of the batch material 7 in the arc furnace 1. Optionally, the electrical signals ES are also taken into account for the evaluation. Owing to this, the arc furnace may deliberately be operated asymmetrically, in particular based on the determination of a scrap metal density, i.e. energy may be delivered asymmetrically to the electrodes 3a, 3b, 3c and/or the position of the electrodes 3a, 3b, 3c may be modified asymmetrically. The electrodes 3a, 3b, 3c are preferably arranged so that they can be displaced vertically.

The scrap metal density is particularly relevant information in particular because lower-density scrap metal melts more rapidly than higher-density scrap metal. In zones with a lower scrap metal density, the input of energy may be reduced, for example inter alia owing to the absence of foam slag. On the other hand, the energy input may be increased by a corresponding amount in zones with a higher scrap metal density.

Based on the evaluation of the measurement data obtained with the aid of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, the electrical signals ES optionally also being taken into account for the evaluation, the supply of chemical energy into the arc furnace 1 may be regulated. The supply of chemical energy influences or causes a combustion process inside the arc furnace 1. The chemical energy may for example be supplied into the arc furnace 1 by manipulating a lance, or by the aid of so-called coherent jets.

The measurement data obtained from the acoustic measurements are processed with the aid of evaluation means 11 to form evaluation data. Evaluation data may for example be employed, as described above, in order to optimize the input of energy into the arc furnace 1. With the aid of the evaluation data, likely scrap metal collapses may also be predicted in advance. Evaluation data are preferably also determined with the aid of electrical measurements. Measurement data and/or evaluation data may be stored in a database (not represented in detail), and may advantageously be used for predictive regulation of the arc furnace 1. Data characteristic of the status of the content of the arc furnace, referred to below as characteristics, are preferably stored in the database. Signal sequences leading up to a scrap metal collapse may, for example, be stored as a collapse characteristic. With the aid of the database and the characteristics stored therein, a preferably self-learning system is formed with the aid of which the energy supply to the electric arc furnace, in particular to the electrodes 3a, 3b, 3c, can be regulated so that future scrap metal collapses or electrode breakages can be avoided.

For the structure-borne noise analysis, or the arrangement of the acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, the furnace vessel 2 is decomposed into segments S, as indicated in FIGS. 2 and 3, preferably by being idealized as a cylindrical vessel. The number of segments S, and horizontal or vertical segments b, b, h, h, and v, v, v, v, v, v, v, v, respectively, is determined by the representation of the accuracy, or by the accuracy required for a certain reliability value for the operation of the arc furnace 1, or for a certain quality of the melt 8.

Essential concepts according to various embodiments may be summarized in the following way:

According to an embodiment, in a method for determining the status of the content of an arc furnace 1 for melting a batch material 7, in particular for melting scrap metal, wherein acoustic signals Np, Ne, Ns which are measured by at least one, preferably a plurality of acoustic sensors 5a, 5b, 5c, 5e, 5g, 5h, 5i, 5r, are evaluated preferably in conjunction with electrical signals which are measured with the aid of at least one electrical sensor 4a, particularly in order to avoid electrode breakages. According to an embodiment, the productivity of the arc furnace 1 is increased by achieving a higher specific melting power via corresponding regulation of the arc furnace 1, and shutdown times are reduced. The specific melt energy is reduced by redistributing energy in the arc furnace 1. Furthermore, the wall wear in the arc furnace 1 is decreasing by reducing the radiation energy on the inner walls.
of the furnace vessel 2 of the arc furnace 1. The electrode consumption can also be reduced according to an embodiment.

What is claimed is:

1. A method for determining a dividedness and/or position of a batch material existing essentially in the solid phase in an arc furnace having a furnace vessel, the method comprising the steps of:
   generator acoustic signals by an arc discharge between an electrode and the batch materials,
   measuring the acoustic signals reflected and/or transmitted through by the batch material by means of acoustic sensor,
wherein at least one acoustic sensor is provided per segment of the furnace vessel subdivided into a plurality of segments, and wherein the dividedness and/or position of the batch material in the arc furnace is determined by evaluating the measured acoustic signals.

2. The method according to claim 1, wherein at least one acoustic sensor, which is arranged on the furnace vessel and on other parts of the arc furnace, is used for measuring the acoustic signals.

3. The method according to claim 1, wherein electrical signals are additionally measured with the aid of at least one electrical sensor in order to determine the dividedness and/or position in the arc furnace.

4. The method according to claim 3, wherein electrical signals are measured between at least two electrodes of the arc furnace by means of an electrical sensor.

5. The method according to claim 1, wherein at least one acoustic sensor, which is arranged on the furnace vessel or the other parts of the arc furnace, is used for measuring the acoustic signals.

6. The method according to claim 1, wherein measurement values and data obtained from the measurement values are stored in a database for early detection of a collapse of the batch material.

7. The method according to claim 6, wherein measurement values and data obtained from the measurement values are compared with measurement values and with data which are stored in the database.

8. A method according to claim 1, further comprising the step of: using the determined dividedness and/or position of the batch material of arc furnace for controlling or regulating the arc furnace.

9. The method according to claim 8, wherein, wherein, in order to avoid breakage of one or more of the electrodes, the energy supply to the electrodes is regulated.

10. The method according to claim 8, wherein the position of the electrodes is regulated.

11. The method according to claim 8, wherein the arc furnace is deliberately operated asymmetrically.

12. The method according to claim 8 wherein the supply of chemical energy into the arc furnace is regulated.

13. A device for determining a dividedness and/or position of a batch material existing essentially in the solid phase in an arc furnace having a furnace vessel, comprising:
   means for generating acoustic signals by an arc discharge between an electrode and the batch material,
   acoustic sensors for measuring the acoustic signals reflected and/or transmitted through by the batch material, wherein at least one acoustic sensor is provided per segment of the furnace vessel subdivided into a plurality of segments, and wherein the dividedness and/or position of the batch material in the arc furnace is determined by evaluating the measured acoustic signals.

14. The device according to claim 13, wherein at least one acoustic sensor, which is arranged on the furnace vessel and on other parts of the arc furnace, is used for measuring the acoustic signals.

15. The device according to claim 13, wherein electrical signals are additionally measured with the aid of at least one electrical sensor in order to determine the dividedness and/or position in the arc furnace.

16. The device according to claim 15, wherein electrical signals are measured between at least two electrodes of the arc furnace by means of an electrical sensor.

17. The device according to claim 13, wherein at least one acoustic sensor, which is arranged on the furnace vessel or on other parts of the arc furnace, is used for measuring the acoustic signals.

18. The method according to claim 1, wherein measurement values and data obtained from the measurement values are stored in a database for early detection of a collapse of the batch material.

19. The method according to claim 1, wherein measurement values or data obtained from the measurement values are stored in a database for early detection of a collapse of the batch material.

20. The method according to claim 19, wherein measurement values or data obtained from the measurement values are compared with measurement values or with data which are stored in the database.

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