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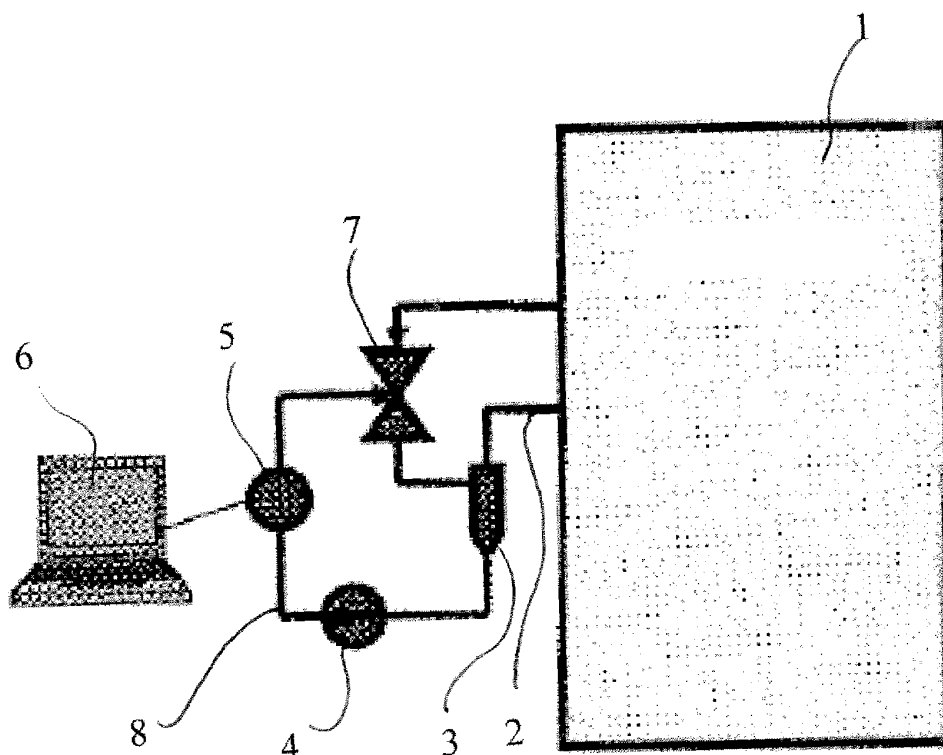
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(54) **Method and apparatus for controlling combustion in a furnace**

(57) Method for controlling of combustion in real time for example in a fluidized bed furnace. The invention is suitable especially for controlling combustion of fuels that have variable composition and are difficult to combust. Such are for example waste fuels and biomasses. In the

method flue gas is taken from the furnace, the flue gas is led to a washer to interact with the washing media of the washer and at least one property of the washing media of the washer is measured for evaluating properties of the gas phase indirectly.

FIG. 1



Description

[0001] The present invention relates to a method according to the preamble of claim 1 for real-time monitoring the combustion process of e.g. a fluidized bed furnace. The present invention is especially suitable for controlling the combustion of fuels with varying compositions and that are difficult to combust. Such fuels include, for example, waste fuels and biomasses.

[0002] The invention also relates to an arrangement for carrying out the method.

[0003] Fluidized bed combustion in its various forms is the most common combustion method in small and medium-sized furnaces. In such a furnace air, mixture of air and flue gas or other gas is blown into a bed consisting of sand or other non-combustible material, the bed thus floating above the bottom of the furnace. Fuel is introduced into this bed. Fluidized bed combustion is well suitable for both sequential and simultaneous combustion of a number of various fuel qualities. Due to the heat contained by the fluidized layer the combustion remains constant even when the quality of fuel changes, which is especially advantageous when burning bio fuels. Due to carbon dioxide emissions trade the demand of bio fuels increases in the market and their price is increased. The competitiveness of peat is also reduced by carbon dioxide emissions trade. At the same time, a number of different waste fuels and cultivated biomasses, the combustion of which is much more problematic than that of wood or peat, have entered the market. Thus the price differences of the fuels will increase and economic reasons force production plants to increase their use of problematic fuels.

[0004] The problem with the combustion of bio fuels can be the high alkali metal and chlorine content of the fuel. Vaporizable alkalis, such as potassium and sodium, can easily react with chlorine in the vapour phase and they form corroding and fouling compounds that also increase the sintering tendency of the fluidized layer. The alkali metals also condense from the vapour phase in hot flue gases onto the cooler surfaces of the superheater. Due to these aspects a layer of impurities, difficult to clean, is formed on the surfaces. In order to control fouling the amount of fuels containing detrimental compounds must be kept sufficiently low. The most difficult situation arises if the alkali chlorides are condensed from gas phase to the surfaces of the heat surfaces, whereby the worst component as far as corrosion is concerned, chlorine, is allowed to accumulate on the layer of impurities and to deteriorate the oxide layer protecting the metal.

[0005] The alkali content can be controlled by analysing the fuel or taking samples from the flue gases and analysing the samples in a laboratory. This is often sufficient in case the composition of the fuel is stable and it is known well enough. As the quality and contents of the fuel changes, there is a need for a real-time or at least reasonably fast contents measurement. Publication US 5432090 describes a method for measuring the alkali

contents in real time by optically measuring the intensity and spectrum of the light emitted by the flame in the furnace. US 5432090 and US 629813 disclose corresponding systems in which flue gases are directed into the flame, the flame being optically monitored. In the solution disclosed in Japanese publication JP 2004286380 the combustion process is indirectly monitored by means of a corrosion sensor and the introduction of waste fuel is changed on the basis of the readings of the sensor. In the solution disclosed in EP 0 603 571 the analysis is made from ash of the combustion.

[0006] The gaseous components of flue gases are difficult to measure directly as elements. Thus, another measurement method would be needed for indicating their amount.

[0007] The aim of the present invention is to produce a method for indirectly measuring the properties of the gas phase in the furnace, especially its fouling properties.

[0008] An especial aim of one embodiment of the invention is to produce a method by means of which the amount of vaporized alkali metals can be analyzed from the flue gases of the furnace.

[0009] The aim of one embodiment of the invention is to provide a method for controlling the alkali content of the flue gases.

[0010] Further, the aim of one embodiment of the invention is to provide a method of controlling the sulphur emission of combustion by dosing the vaporizable alkalis.

[0011] The invention is based on extracting a sample of the flue gases, the sample being directed into a washer and at least one chemical or physical property of the washing medium being measured, thereby producing an indication of the contents of the changes of the gas phase.

[0012] More specifically, the method according to the invention is characterized by what is disclosed in the characterizing part of claim 1.

[0013] The arrangement according to the invention, on the other hand, is characterized by what is disclosed in the characterizing part of claim 11.

[0014] The method according to the invention for controlling the combustion is characterized by what is disclosed in the characterizing part of claim 16.

[0015] Considerable advantages are achieved by means of the invention.

[0016] Immediate advantages can be achieved in the improvement of the utilization factor and reduction of maintenance costs of the steam furnace. However, the largest advantages are achieved in mixed combustion, in which the mixture ratio of the fuels can be safely optimized by means chemical indexes based on measurements. Thus the proportion of cheapest fuels can be maximized, whereby the resulting advantage can be as high as tens of percentage points of fuel costs. The advantage will be especially high in parallel combustion of waste fuels.

[0017] Another application of the invention is controlling the sulphur emissions with vaporizing alkalis (K, Na).

Currently, the application cannot be used because the alkali cannot be controllably dosed and even a small momentary excess amount will cause fouling of the heat surfaces.

[0018] As the emission and utilization requirements as well as the number of fuel alternatives and qualities increase, just a name will no longer sufficiently describe the quality of a fuel, but the chemical composition of the fuel must be known in order to find out the combustion properties of the fuel. The chemical analysis of the fuel and its ash is made in a laboratory. When the chemical analysis data are available, the heat value, composition of resultant flue gases and other data relating to combustion can be calculated. Key figures can also be determined on the basis of the chemical analysis for foreseeing the problems on the flue gas side of the furnace. The problems to be monitored by means of indexes include, among others, fouling of the heat surfaces, corrosion of the heat surfaces and sintering of the fluidized bed. Other aspects to be determined by means of chemical analysis are, for example, heat value of the fuel, parameters describing the combustion conditions (such as adiabatic combustion temperature) and flue gas emissions prior to cleaning.

[0019] The invention makes it possible to develop a continuously developing fuel chemistry control system. The nucleus thereof is measurement technology by means of which the gas chemistry of combustion products can be determined in real time. The measurement points are chosen from various points of the furnace of the furnace and the flue channel. The measurement data are analyzed on the basis of a theory known in gas chemistry and practical comparison data. The comparison data is both general and furnace-specific, whereby new experiences can be immediately utilized.

[0020] The invention can be used for carrying out a continuous control of the fuel introduction so that fouling, utilization of the amount of cheap fuel and, for example, control of sulphur emissions are optimized. Considerable savings are achieved by use of less expensive fuels. Control of fouling will accomplish longer running periods and service intervals. The method according to the invention is especially necessary in plants utilizing bio fuels and waste fuels. Due to the above-mentioned reasons the use of these will in the future increase and in the Nordic countries small and medium-sized furnace plants using these fuels are based on fluidized bed technology. Thus, the invention is especially useful for such plants, but it can also be used in other kinds of furnaces.

[0021] In the following, the invention is disclosed in more detail with reference to the appended drawing, illustrating schematically one arrangement according to the invention.

[0022] The problems with the heat surfaces of the steam furnace are caused by the reaction of alkali metals (Na, K) and chlorine. The idea of the invention is to estimate the amount of these components in gaseous state in the furnace by means of an indirect measurement

method. It is further attempted to determine the concentration of sulphur oxides, in gaseous state as well, in the furnace. The reactions between the gases can be estimated with concentrations (partial pressures of the gases in the furnace) and the reaction balance. The earth alkali metal in chalk form (Ca) is in solid state in the furnace and its reactions can't be estimated with this method, neither is it necessary. Instead, the amounts of vaporizable metals (zinc, aluminium, chromium, copper) can be estimated. These metals can cause problems because they are partly vaporized in the furnace and when they are allowed to react with the gaseous chlorine, the fouling and detrimental emissions caused by them are increased.

[0023] A flue gas removal line 2 to the ceramic filter 3 starts from the furnace 1. The filter 3 is used for separating solid particles from the flue gases, so the measurement result can be made to apply to detrimental materials in the gas phase, especially alkali metals. Subsequent to this the flue gases are directed to a process water circulation 8, in which water is circulated by means of pump 4. The water is cold, so the materials in gaseous phase are condensed in water. The circulation speed and the amount of gas from the furnace are kept constant, whereby the electrical conductivity of the circulated water is changed as a function of the alkali vapour content of the flue gases. The change of the electrical conductivity can further be used as an adjustment criteria for controlling the composition of the fuel mixture or for mixing an additive into the fuel. The change of the electrical conductivity is measured with sensor 5 and the measurement result is processed by means of computer 6. Process water can be added to the circulation via valve 7.

[0024] Instead of a sensor measuring only electrical conductivity the system can also include other sensors for forming a more comprehensive fuel chemistry control system. Usually, the most important measurement value is pH and, in addition thereto, the electrical conductivity. Other values to be measured can include, for example, alkalinity. In principle the washing medium of the washer can be used for measuring any quantities that can be measured with analysis methods.

[0025] If the washing medium is, for example, water, conventional water chemistry analysis methods and sensors can be used the analysis. Especially advantageously process water of the plant is used as the medium of the washer, whereby the values measured for the process water can be used as reference values for the water treated with the washer. The medium of the washer can also be other than water and the washing can be carried out in a number of stages, with a number of mediums, if necessary. In order to improve the selectivity of the measurement and for increasing the sensitivity the washing medium can be treated with various methods, such as with ion exchange, reverse osmosis, buffering, dosing of chemicals, stripping and so on).

[0026] The flue gases are extracted from the part of the furnace or the flue channel from which measurement

data is desired, such as for measuring alkali metal contents the samples are taken from an area where they are in gaseous phase but the combustion reactions have already taken place. Temperature has an especial effect on the sampling place, as the temperature varies in different parts of the furnace and the flue gas channel. Most of the reactions taking place in the furnace and the flue gas channel take place according to temperature, so the sampling place must also be chosen so that the sample can be taken at a temperature suitable for the reactions. In gas phase the alkali metals react with chlorine and produce corrosive compounds. On the other hand, if this area contains sufficient amounts of sulphur, they will react with sulphur and form less detrimental compounds. In addition to alkali metals, for example the proportion of chlorine, sulphur and oxides of sulphur can be measured for producing a more complete analysis. In this case the apparatus must naturally be provided with suitable sensors.

[0027] The invention can be used in both single fuel and multi-fuel furnaces. In single fuel furnaces the invention can also be used for controlling introduction of additional fuels and in multi-fuel furnaces also for adjusting the fuel mixture ratio. In both cases the purpose is to somehow keep the process conditions of the combustion in an area where no detrimental compounds of chlorine and alkali metals are produced. In both cases the combustion temperature can additionally or alternatively be lowered as well. The method works so that when at least a change of pH or increase of electrical conductivity from a furnace-specifically determined maximum is observed by means of the sensor or the sensor system, the control system is sent an indication to commence operations for changing the process conditions. These operations can include decreasing the amount of the chlorine-containing fuel, decreasing the amount of the alkali metal-containing fuel, changing the additives or changing the combustion temperature. The measurement data need not be very accurate in the method, but it will be enough to get an indication that the process is advancing or has advanced into a detrimental area, subsequent to which the control values can be corrected. Because the measurement is continuous, the effect of the change in control can be immediately seen. The adjustment of the combustion process so as to meet the desired process values can be done by means of the measurement result using conventional adjustment technology.

[0028] The following example illustrates clearly the advantages of the invention in multi-fuel combustion. In this waste fuel (REF) is used with peat.

[0029] With peat (price e.g. 7€/MWh) can be combusted a certain amount of inexpensive (price e.g. 0€/MWh) REF fuel, the maximum chlorine content is 15 %. Due to the corrosion risk of the furnace heat surfaces the maximum proportion of REF fuel must be limited to 10 %. The system allows determining a safe maximum proportion of REF fuel so that its amount can be reduced or increased based on how the quality of the peat and the

REF fuel momentarily change. If the fuel effect of the plant is 100 MW and the annual running time is 6000 h, an increase in the proportion of REF fuel from 10 % to 20 % would mean a cost savings of 420 000 € per annum.

Reduction of, e.g. maintenance costs and improved utilization factor, can cause additional cost savings.

[0030] In addition to the above the present invention has other embodiments as well.

[0031] The flue gas can be mixed with clean water or other suitable washing liquid or even with a gas instead of process water. The most important aspect is that the composition changes of the flue gas can be measured from the washing fluid. The term flue gas washer is here used to mean either an actual washer used for cleaning flue gases or most preferably an apparatus in which the sample amount of flue gas is mixed with the analysis liquid used as the washing medium. Instead of directly mixing the flue gases can be directed into contact or interaction through, for example, a semi-permeable membrane, whereby complete mixing does not take place.

[0032] Instead of a ceramic filter another filter with a sufficient separation capability can be used.

Claims

1. A method of monitoring the combustion in a furnace, in which method flue gas is extracted from the furnace, **characterized in that** the flue gas is directed into the washer to interact with the washing medium of the washer and that at least one property of the washing medium of the washer is measured for indirectly estimating the properties of the gas phase.
2. A method according to claim 1, **characterized in that** flue gas is extracted from the furnace (1) as a continuous flow.
3. A method according to any of claims 1-2, **characterized in that** at least the content of at least one detrimental substance is analyzed from the washing medium.
4. A method according to any claims 1-3, **characterized in that** at least pH is determined from the mixture of washing medium and flue gases for indicating the change of content of at least one detrimental substance.
5. A method according to any claims 1-3, **characterized in that** at least electrical conductivity is determined from the mixture of washing medium and flue gases for indicating the change of content of at least one detrimental substance.
6. A method according to any claims 1-5, **characterized in that** at least pH or electrical conductivity is determined from the mixture of washing medium and

flue gases for indicating the change of alkali metal content.

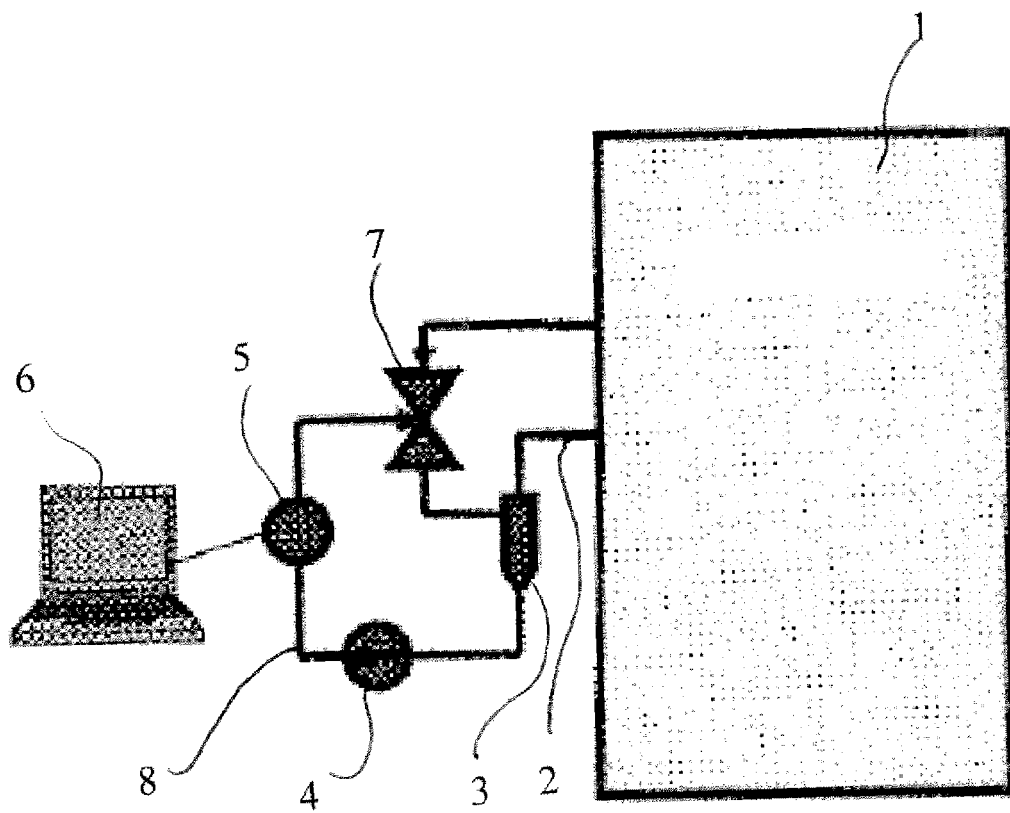
7. A method according to any of claims 1-7, **characterized in that** the flue gases are filtered before mixing with the washing medium. 5
8. A method according to any of claims 1-7, **characterized in that** process water is used as washing medium. 10
9. A method according to any of claims 1-6, **characterized in that** flue gases are mixed with the washing medium. 15
10. A method according to any of claims 1-8, **characterized in that** the flue gases are directed into contact with the washing medium via, for example, a semi-permeable membrane. 20
11. An arrangement for indicating the amount of at least one detrimental substance in the flue gases of a furnace, the arrangement comprising at least one sensor (6), an apparatus for processing the data measured by the sensor and at least one duct (2) for extracting flue gases from the furnace (1) and for bringing them into contact with the washing medium of the flue gas washer **characterized in that** the sensor (6) is arranged to measure the changes caused by the flue gas in the washing medium of the flue gas washer. 25
12. An arrangement according to claim 11, **characterized**
 - **by** a water circulation (4, 7, 8) having a constant amount of water arranged to circulate therein and having at least one sensor (6) arranged in connection therewith, and
 - means (2) for directing a constant flow amount of flue gas into the water circulation. 30
13. An arrangement according to any of claims 11-12, **characterized in that** the at least one sensor (6) is a pH sensor. 35
14. An arrangement according to any of claims 11-13, **characterized in that** the at least one sensor (6) is an electrical conductivity sensor. 40
15. An arrangement according to any of claims 11-14, **characterized by** a filter (3) for removing solids from the flue gas flow prior to directing it into the water circulation. 45
16. A method of controlling the combustion process of a furnace, in which method: 50

- at least one fuel is introduced into the furnace,
- alkali metal content is measured from the flue gases of the furnace,
- the process conditions of the furnace are changed on the basis of the measurement result,

characterized in that

- flue gas is extracted from the furnace (1),
 - flue gas is directed into contact with the washing medium of the flue gas washer, and
 - at least one property of the washing medium is measured.
17. A method according to claim 14, **characterized in that** electrical conductivity is determined from the mixture of water and flue gases for indicating a change of content of alkali metals.
 18. A method according to claim 16 or 17, **characterized in that** the pH of the mixture of washing medium and flue gases is determined for determining its sulphur content.
 19. A method according to any of claims 16-18, **characterized in that** the amount of additive, such as alkali metals, is changed for adjusting the proportions of elements in the flue gases.
 20. A method according to any of claims 16-19 in multi-fuel combustion, **characterized in that** mixture of the fuels is changed for adjusting the element proportion of the flue gases.
 21. A method according to any of claims 16-19, **characterized in that** the combustion temperature is changed.

FIG. 1



REFERENCES CITED IN THE DESCRIPTION

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