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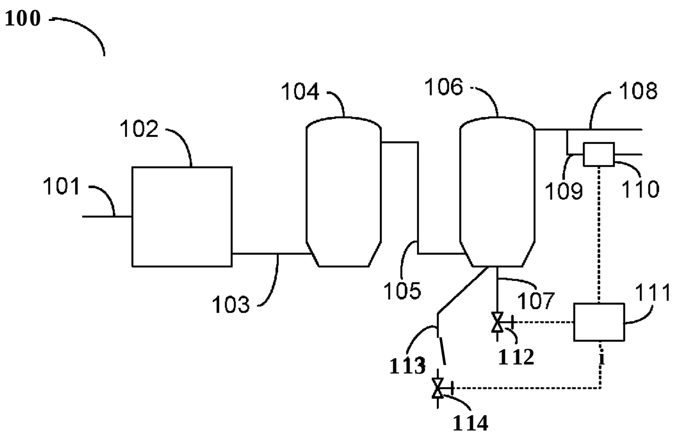

Fig. 1

(57) Abstract: There is provided a process of tar cracking or tar reforming to form a gas product, comprising the steps of: a) cracking or reforming of tar of a tar- containing gas at a temperature and a moisture content form the gas product; b) online measurement of the content of at least one tar compound in the gas product using a photo ionization detector (PID); and c) controlling the temperature and/or the moisture content instep a) based on the tar content(s) measured in step b).

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PROCESS AND SYSTEM FOR CONTROLLED TAR CRACKING OR TAR REFORMING USING A PHOTO IONIZATION DETECTOR

TECHNICAL FIELD

The invention relates to the field of process control.

BACKGROUND

Biomass gasification is considered to be an important technology for future production of power, syngas and biofuels. Tar is one of the most problematic undesired constituents of producer gas and syngas in biomass gasification. Since most applications of producer gas require gas cooling, tars are likely to condense downstream the gasifier, causing fouling or blockages in, for instance, catalytic reactors. Also trace amounts of tar in the process stream can cause deactivation of catalysts, which leads to problems in downstream processing equipment.

There have been several attempts to develop methods to eliminate problems with tar by either circumvent the formation of tars (primary methods) or to remove and/ or convert the tars (secondary methods).

Hence removal of tar from the producer gas has been a highly prioritized topic in research and development aimed at implementing biomass gasification.

SUMMARY

The inventors have realized that gasification and cracking/reforming processes may be controlled based on tar measurements by e.g. a photo ionization detector (PID) and that such a detector is preferably arranged online. For example, the inventors have found that the PID signal responds quickly (normally within a few seconds) to changing tar concentrations, which make the PID particularly suited for the control of a gasification process or a process of tar cracking or tar reforming. Today, the fastest off-line tar analysis method, the SPA method, takes at least 40 minutes for sampling, sample preparation and analysis. Further, it has been found that the PIDs are sensitive to low tar concentrations and that the response is

linear up to high tar concentrations, which make quantification straight-forward and sufficiently reliable.

Individual compounds cannot be quantified directly by the PID. However, the inventors have demonstrated that this is not a major issue, since the concentrations of most individual tar compounds of real producer gas are related to the total tar concentration and the PID measurements are selective for tars.

The inventors have also realized that rapid on-line tar measurement (e.g. PID-based process control) may significantly reduce the steam consumption in the gasification or cracking/reforming process as well as optimise the maintenance management, which are major cost drivers in industrial applications.

Thus, as a first aspect of the present disclosure, there is provided a process of tar cracking/reforming to form a gas product. The process comprises the steps of:

a) cracking/reforming tar of a tar-containing gas at a cracking/reforming temperature and a steam content to form the gas product;

b) online measurement of the content of at least one tar compound in the gas product using a photo ionization detector (PID) or a technology with similar performance, such as GC-MS (Gas Chromotagrophy-Mass Spectrometry) or MBMS (Molecular Beam Mass Spectrometry); and

c) controlling the cracking/reforming temperature and/ or the steam content in step a) based on the tar content(s) measured in step b).

The tar cracking/reforming is preferably is carried out in the presence of a catalyst, such as a nickel-based catalyst, calcined dolomite or iron.

In one embodiment, the cracking/reforming temperature in step a) is increased if the tar content(s) measured in step b) is above a first reference value and/ or decreased if the tar content(s) measured in step b) is below a second reference value. The temperature is normally controlled by controlling an amount of oxygen supplied in step a). For example, this is the case in autothermal reforming (ATR). Here, the "amount" maybe the flow rate of oxygen or an oxygen-containing gas, such as air. The air/oxygen flow rate maybe controlled by means of a valve that is connected to a computing and control device (see below). The cracking/reforming can also be controlled by a thermal management procedure in a step upstream of the cracking/reforming step, such as controlling the air/oxygen flow or temperature in a gasification process producing the tar-containing gas supplied to step a).

In an alternative or complementary embodiment, the steam content in step a) is increased if the tar content(s) measured in step b) is above a first reference value and/ or decreased if the tar content(s) measured in step b) is below a second reference value. The steam content is normally controlled by controlling an amount of water, such as steam, supplied in step a). The water/ steam flow rate may be controlled by means of a valve that is connected to a computing and control device (see below).

The first reference value preferably corresponds to an upper limit, above which the tar contents may cause unacceptable problems. The second reference value preferably corresponds to a lower limit. Tar content(s) below the lower limit may indicate that the excess of steam in the process is unnecessarily high.

The above-mentioned steps of the first aspect may be preceded by a step of gasification of biomass to produce the tar-containing product that is cracked/reformed in step a). The content of at least one tar compound in the tar-containing gas supplied to step a) may be measured online using e.g a PID and the controlling of step c) may be further based on such a measurement.

In one embodiment, step b) further comprises measuring the temperature, pressure, mass flow and/ or steam content of the gas product and the controlling of step c) may be further based on the result of such measurement(s). Also, the controlling of step c) may be indirectly based on the result of on-line gas analysis of CO, H_2, CO_2 and/ or CH_4 in the gas product.

As a second aspect of the present disclosure, there is provided a process of gasification of biomass to form a gas product. The process comprises the steps of:

a) supplying biomass and an amount of an oxidizing medium, such as air, oxygen, water or a mixture thereof, to a gasifier in which a gas product, such as syngas, is formed;

b) performing online measurement of the content of at least one tar compound in the gas product using a photo ionization detector (PID) or a technology with similar performance, such as GC-MS (Gas Chromotagrophy-Mass Spectrometry) or MBMS (Molecular Beam Mass Spectrometry); and

c) controlling the amount oxidizing medium supplied in step a) based on the tar content(s) measured in step b).

If water is supplied in step a, it is normally in the form of steam.

The "amount" of step a) may be the flow rate of the oxidizing medium. The flow rate may be controlled by means of a valve that is connected to a computing and control device (see below).

In one embodiment of the second aspect, the amount of oxidizing medium supplied in step a) is increased if the tar content(s) measured in step b) is above a first reference value and decreased if the tar content(s) measured in step b) is below a second reference value.

In one embodiment of the second aspect, step a) comprises supplying steam and oxygen to the gasifier and step c) further comprises controlling the amount of oxygen and the amount of steam supplied in step a) based on the tar content(s) measured in step b).

The "amount" of oxygen may be the flow rate of oxygen or an oxygen-containing gas, such as air. The oxygen flow rate maybe controlled by means of a valve that is connected to a computing and control device (see below).

The moisture content of the biomass fed to the gasifier may vary. As water is a reactant in the gasification process, it may be beneficial to measure the moisture content of the incoming biomass and adapt the amount of steam supplied in step a) in response thereto. Also, the moisture/ water in the biomass is evaporated in the gasifier, which requires energy. Thus, it may be beneficial to also adapt the amount of oxygen in step a) in response to the measured moisture content of the incoming biomass. This is further discussed below in connection with the fourth aspect.

As in the first aspect, the first reference of the second aspect preferably corresponds to an upper limit, above which the tar contents may cause unacceptable problems. The second reference value of the second aspect preferably corresponds to a lower limit. Tar contents below the lower limit may indicate that the excess of steam in the process is unnecessarily high.

The gas product of the second aspect maybe subjected to catalytic purification upstream and/ or downstream of step b). Such catalytic purification maybe catalytic tar cracking/reforming, e.g. according to the first aspect.

In embodiments of the first and the second aspect, at least two PID devices operating at different wavelengths are used in step b). In such embodiments, the tar measurement is more comprehensive and reliable, which allows for more accurate controlling in step c).

As an example, at least three PID devices operating at different wavelengths are may be used in step b), wherein two of the PID devices are used for detecting different tar compounds and one of the PID devices are used for detecting C1-C6 hydrocarbons, such as ethane, ethane, propane and propene. In such case, the PID instruments used for detecting tar compounds may operate at 8 eV and 12 eV, respectively.

The tar cracking/reforming process of the first aspect maybe performed subsequent to the gasification process of the second aspect. Thus, the gas product of the second aspect may be the tar-containing gas supplied in the first aspect. Thus, the controlling of step c) in the respective processes may be based on the measurements in step b) of both the first and the second aspect.

The inventive concept of the first aspect may also be described as a system. As a third aspect of the present disclosure, there is thus provided a tar cracking/reforming system comprising:

a tar cracker/reformer having an inlet for a tar-containing gas product and a an outlet for a treated (i.e. cracked/reformed) product, wherein the tar cracker/reformer further comprises an oxygen inlet and/or a steam inlet;

an oxygen line connected to the oxygen inlet and/or a steam line connected to the steam inlet;

an oxygen regulating valve arranged on the oxygen line and/or a steam regulating valve arranged on the steam line, wherein the oxygen regulating valve is capable of receiving an oxygen control signal and adjusting a flow of an oxygen-containing gas, such as air, to the tar cracker/ref ormer in response thereto and the steam regulating valve is capable of receiving a steam control signal and adjusting the flow of steam to the tar cracker/reformer in response thereto;

a treated gas product line connected to outlet of the cracker/reformer;

a sample line connected to the treated gas product line, said sample line being arranged to divert a sample stream from the treated gas product line;

a PID device arranged on the sample line, said PID device being capable of producing a signal corresponding to a tar content in the diverted sample stream; and

a computing and control device connected to the PID device and capable of receiving the signal from the PID device and producing the oxygen control signal and/or steam control signal in response thereto, wherein the computing and control device is further connected to the oxygen regulating valve and/ or the steam regulating valve.

Likewise, the inventive concept of the second aspect may also be described as a system. As a fourth aspect of the present disclosure, there is thus provided a gasification system comprising:

a gasifier having a biomass feeder, a steam inlet and a gas product outlet;

a steam line connected to the steam inlet;

a steam regulating valve arranged on the steam line, said steam regulating valve being capable of receiving a steam control signal and adjusting the steam flow to the gasifier in response thereto,

a gas product line connected to the gas product outlet;

a sample line connected to the gas product line, said sample line being arranged to divert a gas product sample stream from the gas product line;

a PID device arranged on the sample line, said PID device being capable of producing a signal corresponding to a tar content in the diverted gas product sample stream; and

a computing and control device connected to the PID device and the steam regulating valve, said computing and control device being capable of receiving the signal from the PID device and producing the steam control signal in response thereto.

The gasification system of the fourth aspect may in one embodiment further comprise an oxygen line connected to an oxygen inlet on the gasifier, wherein an oxygen regulating valve is arranged on the oxygen line, which oxygen regulating valve is capable of receiving an oxygen control signal and adjusting the flow of an oxygen-containing gas, such as air, to the gasifier in response thereto. In such an embodiment, the computing and control device being capable of producing the oxygen control signal in response to the signal from the PID device.

A moisture measurement device maybe arranged upstream of the biomass feeder of the gasifier such that the moisture content of the incoming biomass may be measured. The moisture measurement device may for example comprise a near infrared (NIR) device or another spectroscopic device with similar performance for measuring the moisture content. The moisture measurement device, which is capable of producing a signal corresponding to the moisture content in the biomass, is preferably connected to the computing and control device, which in such case is capable of processing the moisture signal and adapt the steam control signal and/ or the oxygen control signal in response to the measured moisture content.

In the third and fourth aspect, the steam control signal sent to the steam regulating valve and/or the oxygen control signal sent to the oxygen regulating valve may be adapted by the computing and control device in response the temperature, pressure, mass flow and/or steam content of the incoming gas product or the outgoing cracked/reformed gas product. Thus, a thermocouple, a pressure sensor, a flow meter and/ or a steam content detector may be arranged in, on or at the gas product line (fourth aspect) or the treated gas product line (third aspect) and connected to the computing and control device.

Also, the steam control signal sent to the steam regulating valve and/or the oxygen control signal sent to the oxygen regulating valve maybe adapted by the computing and control device in response to the composition of the incoming and/or outgoing gas product. The levels of CO, H_2, CO_2 and CH_4 maybe assessed by a suitable gas analysis detector complying with the process requirements. Thus, a gas analysis device may be arranged in, on or at the gas product line or treated gas product line and connected to the computing and control device.

In one embodiment, the tar cracking/reforming system of the third aspect is arranged downstream of gasification system of the fourth aspect. In such an embodiment, the gas product line of the fourth aspect is connected to the inlet for a tar-containing gas of the third aspect. Also, in such an embodiment, the computing and control device of the fourth aspect and the computing and control device of the third aspect may be the same device. Thus, the respective control signals maybe based on the signals from both PID devices and any other detector or meter connected to the common computing and control device.

As a fifth aspect of the present disclosure, there is provided a naphtha cracking/reforming system comprising:

a naphtha cracker/reformer having a gas inlet, a steam inlet and an outlet for a treated (i.e. cracked or reformed) gas product;

an oxygen line connected to the oxygen inlet;

an oxygen regulating valve arranged on the oxygen line, said oxygen regulating valve being capable of receiving an oxygen control signal and adjusting the flow of an oxygen-containing gas, such as air, to the naphtha cracker/reformer in response thereto;

a steam line connected to the steam inlet;

a steam regulating valve arranged on the steam line, said steam regulating valve being capable of receiving a steam control signal and adjusting the steam flow to the naphtha cracker/reformer in response thereto;

a treated gas product line connected to the outlet for the treated gas;

a sample line connected to the treated gas product line, said sample line being arranged to divert a sample stream from the treated gas product line;

a PID device arranged on the sample line, said PID device being capable of producing a signal corresponding to a content of at least one saturated and/ or unsaturated hydrocarbon in the diverted sample stream;

a computing and control device connected to the PID device and the oxygen regulating valve, said computing and control device being capable of receiving the signal from the PID device and producing the steam control signal and/or the oxygen control signal and in response thereto.

A method corresponding to the system of the fifth aspect is also provided.

The at least one hydrocarbon monitored in the system or method may for example be benzene, propene, toluene, fenol, biphenyl, pyrene, cresol, acenaphthene, acenaphthylene, fluorine, indane, indene and/or naphthalene.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 and Fig. 2 show gasification and tar cracking/reforming processes involving PID-based process control according to two embodiments of the present disclosure.

Fig. 3 shows an embodiment of a computing and control device.

DETAILED DESCRIPTION

In the context of the present disclosure, "tars" refer to aromatic hydrocarbons having a molecular weight above 78.

PIDs are commercially available and have traditionally primarily been used as gas chromatography detectors. The ultraviolet (UV) lamp is an important part of the PID since it determines the compounds that can be detected. Depending on the type of gas inside the lamp, the emitted light has different wavelengths. For example, a lamp filled with krypton emits a wavelength of 10.6 eV, a lamp filled with argon emits a wavelength of 11.7 eV and a lamp filled with xenon emits a wavelength of 8.4 eV. According to the operating principle of the PID, electrons will be temporary removed from the molecules of the compounds of interest, providing that the ionization potential of the compounds is similar to or lower than the energy of the photons generated by the UV-light. This results in positively charged molecules that generate a current, which is directly proportional to the concentration of the compound. Many different molecules will be simultaneously detected and therefore the PID signal will represent the total signal from all simultaneously excited compounds. The selectivity is chosen by selecting the energy of the UV-light emitted from the lamp. Only a small fraction of the molecules are exited and the process is generally reversible. The analysis method is therefore considered to be non-destructive. Therefore the outlet of sample stream can be connected in series with subsequent analytic techniques, such as a mass spectrometer (MS) or a flame ionization detector (FID). This enables simultaneous and selective detection from several detectors.

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

Fig. 1 shows a gasification process according to a non-limiting embodiment of the present disclosure. Biomass is fed 101 to a dryer 102, to which heat is also supplied such that the moisture content of the biomass is reduced. Dried biomass is routed 103 to a gasifier 104, in which it is heated to a temperature above 700 °C. Also, one or more oxidizing agents, such as air, oxygen and/or steam, is/are fed to the gasifier. The gasifier maybe a fixed bed gasifier, a fluidized bed gasifier, and entrained flow gasifier or an indirect gasifier. The conditions in the gasifier 104 are controlled to prevent combustion of the biomass. If the temperature in the gasifier is below 1000 °C, a gas product primarily suited for production of synthetic natural gas or electricity is obtained. If however the temperature is above 1200 °C, the gas product is more suited for production of Fischer-Tropsch diesel, methanol, ammonia, hydrogen or other chemicals.

The gas product produced by the gasification in the gasifier 104 contains tar, which may foul the equipment used for further processing of the gas product. Further, many tars are carcinogenic and their levels may depending on the application have to be reduced to meet health and environmental demands. Therefore, the tar-containing gas product from the gasifier 104 is that is fed to a tar cracker 106 via a first gas product line 105. The conditions in the tar cracker 106 are adapted to reform the tar, while leaving as much as possible of the lower hydrocarbons intact. The tar cracker 106 preferably contains a tar cracking catalyst, such as calcined dolomite or olivine. The temperature in the tar cracker 106 is determined by the amount of oxygen fed to the cracking process. An oxygen supply line 107 feeds oxygen (e.g. in the form of air) to the tar cracker 106. The more oxygen that is supplied to the process, the higher the temperature and the efficiency of the tar conversion. However, higher amounts of oxygen also reduce the overall yield of the gasification process as desired components of the gas product are oxidized. Further, the gas product of the cracker is diluted if air is used. The gas product from the tar cracker 106 is routed to further processing via a second gas product line 108. Further, moisture is normally added to the tar cracker. Thus, a water supply line 113 maybe arranged to feed water (normally in the form of steam) to the tar cracker 106. Traditionally, a substantial excess of steam has often been added to tar cracking processes to ensure high tar conversion. However, the production of steam is costly. Further, the excess steam dilutes the gas product and reduces its value.

A sample of the gas product is diverted from the second gas product line 108 and routed to a PID arrangement 110 via a sample line 109. The PID arrangement 110 produces a signal corresponding to the tar content in the sample. The signal is processed by a computing and control device 111, to which the PID arrangement 110 is connected. The computing and control device 111 is also connected to an oxygen regulating valve 112 arranged on the oxygen supply line 107. In response to the signal from the PID arrangement 110, the computing and control device 111 produces a control signal that is sent to the regulating valve 112. Thus, the oxygen supply to the cracking process maybe controlled in response to the tar content in the resulting gas product. Thereby, the oxygen supply maybe optimized such that the tar content in the gas product is kept within an acceptable range without an unnecessary reduction of the overall yield of the gasification process or an unnecessary dilution of the gas product.

The computing and control device 111 may also be connected to a steam regulating valve 114 arranged on the water supply line 113. In response to the signal from the PID arrangement 110, the computing and control device 111 may thus produce a steam control signal that is sent to the steam regulating valve 114. Thus, the steam supply to the cracking process maybe controlled in response to the tar contents in the resulting gas product. Thereby, the steam supply maybe optimized such that the tar content in the gas product is kept within an acceptable range without an unnecessary reduction of the overall yield of the gasification process or an unnecessary dilution of the gas product.

Cooling of the gas product from the gasifier 106 is normally necessary. Therefore, a gas cooler (not shown) may be provided on the second gas product line 108. During cooling, the temperature of the gas product may fall below the condensation temperature for many tar compounds. Therefore, the sample line 109 is preferably connected to the second gas product line 108 upstream of the gas cooler to avoid tar condensation before the tar measurement in the PID arrangement 110.

Fig. 2 shows a gasification process according to another non-limiting embodiment of the present disclosure. Abiomass feeder 201 feeds biomass to a gasifier 202. Further, steam is fed to the gasifier 202 via a steam supply line 203 and oxygen is fed to the gasifier 202 via an oxygen supply line 204. The gas product from the gasifier 202 is routed to further processing via a gas product line 205. Gasification of biomass may produce substantial levels of tars, in particular if the supply of oxidizing agent (e.g. steam, oxygen and/or air) is limited. A high tar content may foul the equipment in downstream processing of the gas product. Also, tars are associated with health and environmental issues, as discussed above. Therefore, a substantial excess of steam has been added to the gasification process to avoid the risk of high tar contents. However, the production of steam is costly. Further, the excess steam dilutes the gas product and reduces its value. In the embodiment of Fig. 2, the tar contents are monitored. A sample of the gas product is diverted from the gas product line 205 and routed to a PID arrangement 207 via a sample line 206. The PID arrangement 207 produces a signal corresponding to the tar content in the sample. The signal is processed by a computing and control device 208, to which the PID arrangement is connected. The computing and control device 208 is also connected to a steam regulating valve 209 arranged on the steam supply line 203. In response to the signal from the PID arrangement 207, the computing and control device 208 produces a steam control signal that is sent to the steam regulating valve 209. Thus, the steam supply to the gasification process may be controlled in response to the tar content in the resulting gas product. Thereby, the steam supply may be optimized such that the tar content in the gas product is low (e.g. below a maximum value) without an unnecessary excessive steam supply.

The oxygen supply controls the temperature in the gasifier 202. As mentioned above, the temperature affects the tar content in the gas product. If the oxygen-containing gas supplied to the gasifier 202 is air, it is particularly beneficial to control the air supply such that unnecessary dilution of the gas product with air-derived nitrogen is avoided. Thus, not only the steam supply, but also the oxygen supply may be controlled in response to the tar content detected in the PID arrangement 207. Accordingly, an oxygen regulating valve (not shown) maybe arranged on the oxygen supply line 204 and connected to the computing and control device 208. In such case, the computing and control device 208 can produce an oxygen control signal that is sent to the oxygen regulating valve in response to the signal from the PID arrangement 207.

The PID arrangement 207 may comprise one or more PID devices. A PID device for detecting tar compounds may for example operate at 9.5 or 10.6 eV. Thus, the PID arrangement 207 may comprise a first PID device operating at 9.5 eV and a second PID device operating at 10.6 eV.

It may also be beneficial to control the steam supply and/ or the oxygen supply in response to the contents of lower hydrocarbons **(Ci-C_6** hydrocarbons) in the gas product. Such contents maybe measured by a PID device operating at 9.5 or 11.7 eV. Thus, the PID arrangement 207 may comprise a PID device for lower hydrocarbons and the computing and control device 208 may adapt the steam control signal and/or the oxygen control signal in response to the to the signal from such a PID device.

Alternatively, the contents of lower hydrocarbons maybe measured by a flame ionization detector (FID) provided that a device for condensation of tar compounds in the gas product is arranged upstream of it. Thus, the computing and control device 208 may adapt the steam control signal and/or the oxygen control signal in response to the signal from a FID.

Downstream of the connection to the PID arrangement 207, the gas product is purified in a purification arrangement 215. The purified gas is then routed to a refiner 211 via a line 210 for purified gas. The purification arrangement 215 may comprise one or more devices for removal of particulates, sulphur compounds, nitrogen compounds, halogens, volatile metals and/or tar. However, a device for removal of particulate matter (e.g. a filter) may be arranged upstream of the connection to the PID arrangement 207.

Cooling of the gas product from the gasifier 202 is normally necessary. Therefore, a gas cooler (not shown) may be provided on the gas product line 205. As also discussed above, the temperature of the gas product may fall below the condensation temperature for many tar compounds during cooling. Therefore, the sample line 206 (i.e. the connection to the PID arrangement 207) is preferably connected to the gas product line 205 upstream of the gas cooler to avoid tar condensation before the tar measurement in the PID arrangement 207.

The purification arrangement 215 may thus comprise a device for catalytic tar cracking (not shown). Such a cracker may reform the tar and could thus be regarded as a reformer. Downstream of such a device for catalytic tar cracking, a second sample line 212 may divert a gas sample from the line 210 for purified gas to a second PID arrangement 213. The second PID arrangement downstream of the cracking device may be upstream or downstream of a device for removal of particulate matter also comprised in the purification arrangement 215. The second PID arrangement 213 is connected to the computing and control device 208. Alternatively, the second PID arrangement maybe connected to an independent computing device (not shown). Thus, the tar content in the purified gas product maybe monitored. If the detected tar content in the purified gas product is too high, e.g. above a predetermined maximum value, an operator maybe alerted. Alternatively, the operator may be alerted if the degree of reduction of the tar content is insufficient over the device for catalytic tar cracking. Such a degree of reduction may be calculated using the signal from the PID arrangement 207 to obtain the incoming ("in") tar concentration and the signal from the second PID arrangement 213 to obtain the resulting ("out") tar concentration. Thus, the formula for the degree of reduction maybe $([tar]_{in}-[tar]_{out})/[tar]_{in}$.

In response to the alert, the catalyst of the device for catalytic tar cracking maybe regenerated. In one embodiment, the device for catalytic tar cracking comprises two catalytic units arranged in parallel, wherein one may be used for cracking while the other is regenerated following an alert about high tar contents detected by the second PID arrangement 213. The switch between the two catalytic units may also be an automatic response to a tar content above a reference maximum value or an insufficient degree of reduction.

The moisture content of the biomass fed to the gasifier 202 may vary. As water is a reactant in the gasification process, it may be beneficial to measure the moisture content of the incoming biomass and adapt the amount of steam supplied via the steam supply line 203 in response thereto to balance the reaction in the gasifier 202. Also, the moisture/water in the biomass is evaporated in the gasifier 202, which requires energy. Thus, it maybe beneficial to also adapt the amount of oxygen supplied via the oxygen supply line 204 in response to the measured moisture content of the incoming biomass. Therefore, a moisture measurement device 214 may be arranged upstream of the biomass feeder 201. The moisture measurement device 214 may for example comprise a NIR camera for measuring the moisture content. The moisture measurement device 214 produces a signal corresponding to the moisture content in the biomass. The signal is processed by the computing and control device 208, to which moisture measurement device 214 is connected. Thus, the steam control signal sent to the steam regulating valve 209 and/or the oxygen control signal sent to the oxygen regulating valve may be adapted by the computing and control device 208 in response to the measured moisture content of the biomass.

In addition, the steam control signal sent to the steam regulating valve 209 and/or the oxygen control signal sent to the oxygen regulating valve maybe adapted by the computing and control device 208 in response the temperature, pressure, mass flow and/or moisture content of the gas product. Thus, a thermometer, a pressure sensor, a flow meter and/or a moisture meter maybe arranged in, on or at the gas product line 205 and/or the purification arrangement 215 and connected to the computing and control device 208. Similarly, a thermometer, a pressure sensor, a flow meter and/or a moisture meter may be arranged in, on or at the cracking device of purification arrangement 215, and connected to the computing and control device 208.

Also, the steam control signal sent to the steam regulating valve 209 and/or the oxygen control signal sent to the oxygen regulating valve maybe adapted by the computing and control device 208 in response to the composition of the gas product. The levels of CO, H_2, CO_2 and CH_4 may be assessed by a thermal conductivity detector (TCD). Thus, a TCD device may be arranged in, on or at the gas product line 205, the purified gas line 210 and/ or the cracking device of purification arrangement 215, and connected to the computing and control device 208.

In some embodiments, the control device 208 maybe connected to sensors for measuring oxygen concentration and/or moisture (H_2O) concentration in the cracking device of purification arrangement 215, and/ or may control supply of oxygen and/ or moisture to said cracking device for tar reforming.

The computing and control device 111, 208, 300 normally comprises a processor 301, an input/output interface 302 and a memory 303. The memory 303 comprises data about how the PID signal is related to the tar content. Such data may be empirical, i.e. based on previous measurements of tar compounds in process streams. Thus, by means of the processor 301, a tar value corresponding to the PID signal can be compared to a reference value stored in the memory 302. Further, based on the comparison the processor 301 may determine one or more control signals (e.g. the steam control signal and/ or the oxygen control signal) that is/ are sent by the input/ output interface 302. Likewise, values corresponding to the signals from the other meters/measurement devices maybe determined by the processor 301 and compared to reference values using data stored in the memory 302. The one or more control signals may then be determined taking also these comparisons into account.

CLAIMS

1. A process of tar cracking or tar reforming to form a gas product, comprising the steps of:
a) cracking or reforming of tar of a tar-containing gas at a temperature and a moisture content to form the gas product;
b) online measurement of a content of at least one tar compound in the gas product using a photo ionization detector (PID); and
c) controlling the temperature and/ or the moisture content in step a) based on the tar content(s) measured in step b).

2. The process of claim 1, wherein the cracking or reforming of step a) is carried out in the presence of a catalyst.

3. The process of claim 1 or 2, wherein the temperature and/ or moisture content in step a) is increased if the tar content(s) measured in step b) is above a first reference value and decreased if the tar content(s) measured in step b) is below a second reference value.

4. The process of anyone of claims 1-3, wherein the temperature is controlled by controlling an amount of oxygen supplied in step a) and/or the moisture content is controlled by controlling an amount of steam supplied in step a).

5. The process of anyone of claims 1-4, further comprising the step of gasification of biomass to provide the tar-containing product that is cracked or reformed in step a).

6. A process of gasification of biomass to form a gas product, comprising the steps of:
a) supplying biomass and an amount of an oxidizing medium, such as air, oxygen, water or a mixture thereof, to a gasifier in which a gas product is formed;

b) performing online measurement of the content of at least one tar compound in the gas product using a photo ionization detector (PID); and

c) controlling the amount of oxidizing medium supplied in step a) based on the tar content(s) measured in step b).

7. The process of claim 6, wherein the amount of oxidizing medium supplied in step a) is increased if the tar content(s) measured in step b) is above a first reference value and decreased if the tar content(s) measured in step b) is below a second reference value.

8. The process of claim 6 or 7, wherein the gas product is syngas.

9. The process of anyone of claims 6-8, wherein the gas product is subjected to catalytic purification upstream and/or downstream of step b).

10. The process of anyone of the preceding claims, wherein at least two PID devices operating at different wavelengths are used in step b).

11. The process of claim 10, wherein at least three PID devices operating at different wavelengths are used in step b), two of said PID devices being used for detecting different tar compounds and one of said PID devices being used for detecting C1-C6 hydrocarbons, such as ethane, ethane, propane and propene.

12. The process of claim 10 or 11, wherein the PID instruments used for detecting tar compounds operate at 8 eV and 12 eV, respectively.

13. A system for cracking or reforming of tar comprising:

a tar cracker or tar reformer comprising an inlet for a tar-containing gas product and an outlet for a treated gas product, wherein the tar cracker or tar reformer further comprises an oxygen inlet and/or a steam inlet;

an oxygen line connected to the oxygen inlet and/or a steam line connected to the steam inlet;

an oxygen regulating valve arranged on the oxygen line and/or a steam regulating valve arranged on the steam line, wherein the oxygen regulating valve is capable of receiving an oxygen control signal and adjusting the flow of an oxygen-containing gas, such as air, to the tar cracker or tar reformer in response thereto and the steam regulating valve is capable of receiving a steam control signal and adjusting the flow of steam to the tar or tar reformer in response thereto;

a treated gas product line connected to the treated gas product outlet;

a sample line connected to the treated gas product line, said sample line being arranged to divert a sample stream from the treated gas product line;

a PID device arranged on the sample line, said PID device being capable of producing a signal corresponding to a tar content in the diverted sample stream; and

a computing and control device connected to the PID device and capable of receiving the signal from the PID device and producing the oxygen control signal and/ or steam control signal in response thereto, wherein the computing and control device is further connected to the oxygen regulating valve and/ or the steam regulating valve.

14. A gasification system comprising:

a gasifier having a biomass inlet, a steam inlet and a gas product outlet;

a steam line connected to the steam inlet;

a steam regulating valve arranged on the steam line, said steam regulating valve being capable of receiving a steam control signal and adjusting the steam flow to the gasifier in response thereto,

a gas product line connected to the gas product outlet;

a sample line connected to the gas product line, said sample line being arranged to divert a gas product sample stream from the gas product line;

a PID device arranged on the sample line, said PID device being capable of producing a signal corresponding to a tar content in the diverted gas product sample stream; and

a computing and control device connected to the PID device and the steam regulating valve, said computing and control device being capable of receiving the signal from the PID device and producing the steam control signal in response thereto.

15. A naphtha cracking or naphtha reforming system comprising:

a naphtha cracker or naphtha reformer having a gas inlet, a steam inlet and an outlet for a treated gas product;

an oxygen line connected to the oxygen inlet;

an oxygen regulating valve arranged on the oxygen line, said oxygen regulating valve being capable of receiving an oxygen control signal and adjusting a flow of an oxygen-containing gas, such as air, to the naphtha cracker or naphtha reformer in response thereto;

a steam line connected to the steam inlet;

a steam regulating valve arranged on the steam line, said steam regulating valve being capable of receiving a steam control signal and adjusting the steam flow to the naphtha cracker or naphtha reformer in response thereto;

a treated gas product line connected to the outlet for the treated gas product;

a sample line connected to the treated gas product line, said sample line being arranged to divert a sample stream from the treated gas product line;

a PID device arranged on the sample line, said PID device being capable of producing a signal corresponding to a content of at least one saturated and/ or unsaturated hydrocarbon in the diverted sample stream;

a computing and control device connected to the PID device and the oxygen regulating valve, said computing and control device being capable of receiving the signal from the PID device and producing the steam control signal and/ or the oxygen control signal and in response thereto.

16. The system of claim 15, wherein the at least one saturated and/ or unsaturated hydrocarbon is benzene, propene, toluene, fenol, biphenyl, pyrene, cresol, acenaphthene, acenaphthylene, fluorine, indane, indene and/or naphthalene.

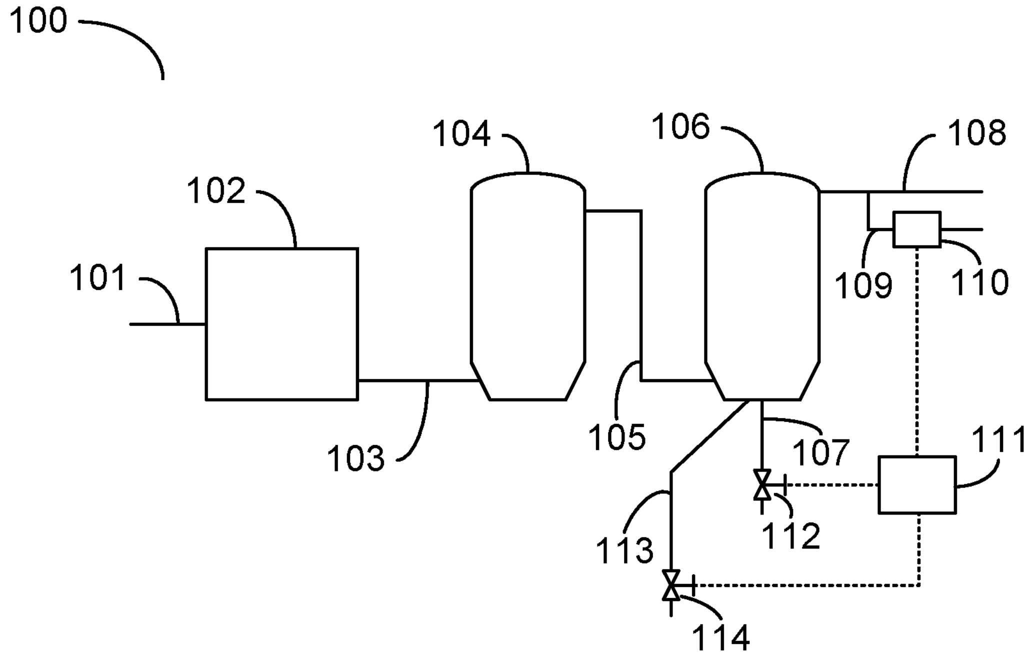
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Fig. 1

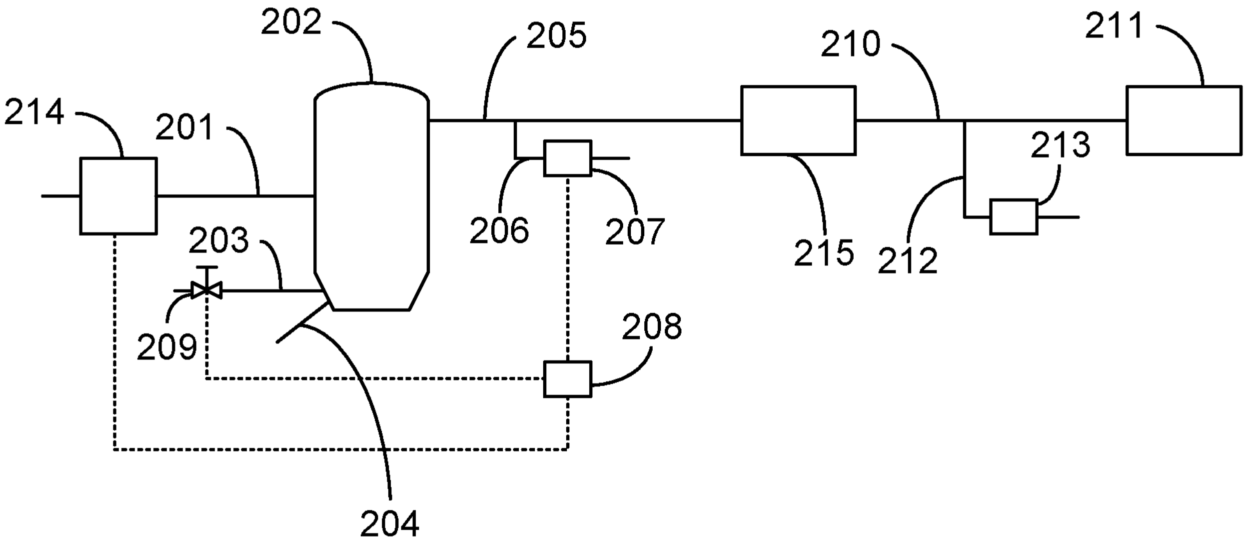
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Fig. 2

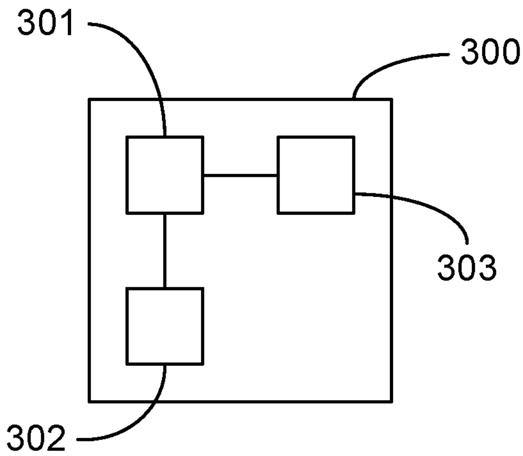

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2014/050296

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C10B, C10C, C10J, G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC, Scopus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2295526 A1 (PROTODESIGN S R L), 16 March 2011 (2011-03-16); whole document --	1-16
A	WO 2009153264 A1 (COMMISSARIAT ENERGIE ATOMIQUE ET AL), 23 December 2009 (2009-12-23); whole document --	1-16
A	US 20100043528 A1 (BROTHIER MERYL ET AL), 25 February 2010 (2010-02-25); whole document --	1-16

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international fding date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18-06-2014	18-06-2014
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Johan Kjellgren Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Ahmadi, M., Brage, C , Sjostrom, K., Engvall, K., Knoef, H., Van De Beld, B. "Development of an on-line tar measurement method based on photo ionization technique" 201 1 Catalysis Today 176 (1) , pp. 250-252; whole document --	1-16
A	US 201 00045300 A 1 (BROTHIER MERYL ET AL), 25 February 201 0 (201 0-02-25); whole document -- --------	1-16

Continuation of: second sheet

International Patent Classification (IPC)

C10J 3/72 (2006.01)
C10B 53/00 (2006.01)
C10C 1/19 (2006.01)
C10J 3/84 (2006.01)
G05B 11/01 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2014/050296

EP	2295526	A1	16/03/2011	IT	AV20090001	A1	30/10/2010
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US	20100043528	A1	25/02/2010	BR	PI0720559	A2	14/01/2014
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				FR	2910966	B1	17/04/2009
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				US	8054082	B2	08/11/2011
				WO	2008080987	A1	10/07/2008
				ZA	200903675	A	28/04/2010