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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention generally relates to conversion of carbonaceous materials into desirable gaseous products such as synthesis gas. More specifically the present invention relates to a gasification system for gasifying carbonaceous material and a method thereof.

BACKGROUND

[0002] Gasification can be described as a process where organic or fossil fuel based carbonaceous materials are converted into a product gas of varying molecular weights, such as e.g. carbon monoxide, hydrogen and carbon dioxide. This is generally achieved through a thermo-chemical reaction where the carbonaceous materials react with a controlled amount of oxygen, steam and/or carbon dioxide acting as an oxidant, the resulting product gas mixture is often called synthesis gas (also known as synthetic gas or syngas).

[0003] The synthesis gas can later be used as a fuel gas where it is burned directly as fuel to produce heat and/or electric power or as an intermediate for other multiple uses. The power derived from gasification of bio-based feedstock is considered to be a source of renewable energy and the gasification industry has attracted a lot of interest during these last decades.

[0004] Further, gasification differs from other, more traditional energy-generating processes, in that it is not a combustion process, but rather a conversion process. Instead of the carbonaceous feedstock being wholly burned in air to create heat to raise steam which is used to drive turbines, the feedstock to be gasified is incompletely combusted to create the syngas which then at a later stage is completely combusted in order to release the remaining energy. The atmosphere within the chamber is deprived of oxygen, and the result is complex series of reactions of the feedstock to produce synthesis gas. The synthesis gas can be cleaned relatively easily, given the much lower volume of raw synthesis gas to be treated compared to the large volume of flue gases that need to be treated in conventional post-combustion cleaning processes. In fact, gasification processes used today are already able to clean synthesis gas beyond many environmental requirements. The clean synthesis gas can subsequently be combusted in turbines or engines using higher temperature (more efficient) cycles than the conventional steam cycles associated with burning carbonaceous fuels, allowing possible efficiency improvements. Synthesis gas can also be used in fuel cells and fuel cell-based cycles with yet even higher efficiencies and exceptionally low emissions of pollutants. The (energy) efficiency of a gasification system is often measured in terms of cold gas efficiency (CGE) which is the he ratio between the chemical energy in the product gas compared to the chemical energy in the fuel.

[0005] There is disclosed in US2002/020112 A1 a process and apparatus for manufacturing gas and liquids from trash, other waste materials and other solid fuels.

[0006] There is also disclosed in CN105602623 A, a biomass gasification furnace. There is also disclosed in US2010/037519 A1 a downdraft gasifier.

[0007] Also there is a reactor disclosed in DE202009002781 U1, for thermal treatment of use material.

[0008] Nevertheless, even with the positive environmental aspects there is still a need for increased efficiency while still keeping the gasification system cost effective.

[0009] There is therefore a need in the industry for a new and improved gasification system and method which is energy efficient but at the same time reliable and cost-effective.

SUMMARY OF THE INVENTION

[0010] It is accordingly an object of the present invention to provide a gasification system and a method for gasifying carbonaceous material which alleviates all or at least some of the above-discussed drawbacks of presently known systems. In more detail it is an object of the present invention to provide for a gasification system and method which is more cost effective and energy efficient compared to the prior art.

[0011] This object is achieved by means of a gasification system and method as defined in the appended claims.

[0012] According to a first aspect of the present invention there is provided a gasification system for gasifying a carbonaceous material, wherein the gasification system comprises:

a gasification chamber having an upper section and a lower section;
at least one screw-feeder for injecting and dispersing a carbonaceous solid fuel with a particle size of less than 10 mm (and oxidant in some embodiments) into the upper section whereby synthesis gas and residual char is generated by a first thermo-chemical reaction occurring during a downwardly directed falling of the carbonaceous fuel towards a bottom portion of the lower section;
a char bed disposed in the lower section, the char bed being formed by residual char generated in the first thermo-chemical reaction;
at least one gas-inlet at a bottom portion of the lower section for injecting oxidant into the char bed whereby synthesis gas is generated by a second thermo-chemical reaction from the residual char;
wherein the at least one screw feeder is arranged at a predefined distance from the bottom portion, wherein the predefined distance is at least 30% of a vertical extension of the gasification chamber, preferably the predefined distance is at least 50 % of the

vertical extension of the gasification chamber and most preferably the predefined distance is 60% of the vertical extension of the gasification chamber.

[0013] Hereby, an efficient and cost effective gasification system is presented. In more detail, the gasification system according to the first aspect of the present invention is less complex and more cost-effective as compared to known prior art solutions and efficiently utilizes the residual char from the first thermo-chemical reaction to form a char bed. The gasification system further has a gas-inlet at the bottom portion of the lower section for injecting oxidant into the char bed in order to form an at least partly fluidizing/fluidized char bed whereby a second thermo-chemical reaction can occur in order to increase the synthesis gas output of the system. The oxidant (oxidizing agent) can for example be air, steam or oxygen while the carbonaceous particulate fuel can for example be one or more of the following: biomass, biofuel, coal, wood, agricultural residues such as e.g. husk, digestate, manure, dewatered waste water, barch, straw, peat, fibre residue.

[0014] Furthermore, the gasification system may be provided with one or more oxidant inlets at the upper section which is/are independent from the screw-feeder and/or oxidant may be injected via the same screw-feeder as the carbonaceous solid fuel.

[0015] The gasification chamber is preferably cylindrically shaped and has a cylindrical inner wall/surface enclosing an internal cavity. Moreover, the inner wall of the gasification chamber can be at least partly curved, e.g. by being cylindrically shaped such that a part of said curved wall forms part of a cylinder. According to at least one embodiment, a cross section of said gasification chamber is circular, the cross section being in a plane perpendicular to a longituindal/vertical axis (z-axis in case of a cylindrical shape) of the gasification chamber. The lower section, may have an inner wall/surface with a tapered cylindrical (i.e. conical) character where a bottom portion has the smallest diameter, however, configurations where the gasification chamber has a more uniform character are also feasible, i.e. the upper section and the lower section may be arranged to have the same diameter. Further, the upper section and the lower section of the gasification chamber are preferably portions of a single vessel or container or at least in fluid connection with each other.

[0016] The present invention is based on the realization that conversion of carbonaceous matter to synthesis gas (or syngas) occurs step-wise by means of different thermo-chemical reactions with differing reaction conditions and that such differing reactions can be created in a single chamber gasification reactor. In particular the invention is based on the realization that the first release of volatiles (volatile matter) occurs more rapidly and at a lower temperature than the following gasification of carbon which demands a longer residence time and higher temperature. By arranging the screw-feeder at a predefined "height" of the gasification chamber, and thereby configuring the gasification system such that the particulate carbonaceous fuel can travel downwardly (by means of gravitational force) through different reaction zones within the gasification chamber a complete conversion with high efficiency is achieved.

[0017] Thus, the present inventors realized that by arranging controlled falling of fine fraction carbonaceous fuel from a top section to a lower section of a gasification chamber, a first thermo-chemical reaction (flash pyrolysis) of said fuel can be achieved. The gravitational falling also provides an advantageous condition as it means that the fuel is dispersed in the hot gas of the gasification. A high level of such dispersion is achieved by the injecting of the feedstock into the gasification chamber due to the usage of a screwfeeder as feeding device. Other injection means, such as for example pneumatically by the using a blower means that the feedstock enters with a higher velocity thereby inhibiting the spread (dispersion) of the feedstock in the surrounding gas.

[0018] Blower-fed injectors tend to push the feedstock towards the inner wall of the gasification chamber thereby inhibiting the desired maximized mixing of the feedstock with the gas. Such dispersion increases the contact area between the fuel and the gas which enhances the thermo-chemical reactivity. Also, screw-feeding, in contrast to blowing, enables that only a small amount of oxidizing air is injected in the same injector as the feedstock. In this way the distribution of oxidant in the gasification chamber can be controlled as more oxidant can be injected at other locations in the gasification chamber than directly with the feedstock injection.

[0019] It is desirable to control (and limit) the total amount of injected oxidant into the gasification chamber in order to achieve high conversion efficiency. When the residues of the carbonaceous fuel (mainly char) reach the bottom portion of the lower section they form a char bed. By providing additional oxidant directly into this bed, favourable conditions, i.e. higher temperature and increased residence times, can be achieved thus enabling the second thermo-chemical reaction (carbon gasification). The residence time in the char bed can be relatively long and controlled by means of the rate of rejecting/removing the remaining char ashes from the bed. The residence time of the carbonaceous fuel during the downwardly directed falling (during the first thermo-chemical reaction) is preferably at least 1 second and more preferably at least 2 seconds, in order to for example ensure release of volatile matter in the first thermo-chemical reaction. The residence time of the carbonaceous fuel during the downwardly directed falling can for example be controlled by controlling the position of the screw feeder at the gasification chamber, injection velocities of fuel or oxidant, oxidant supply, etc. In other words, the residence time of the first thermo-chemical reaction can be controlled by determining the distance between the fuel injector and the bottom portion of the gasification reactor and by the injection velocities of feedstock and oxidant.

[0020] The complete gasification system enables increased energy efficiency as compared to prior known solutions. In particular, unnecessary heating of the volatile gas generated by the flash pyrolysis (first thermochemical reaction) is avoided, thereby minimizing the combustion of such volatile gas. This would be the case if the residual char was converted to synthesis gas in the same section as the first thermo-chemical pyrolysis process (upper section in the present context).

[0021] The pyrolysis process can be said to be a process where volatile matter in the carbonaceous particulate material are released and converted to permanent gases, pyrolysis-oil and tar. Furthermore the residual char is efficiently handled and utilized (for forming the hot fluidizing bed) whereby costs can be reduced since there is no need to lead off the extremely high temperature residual char particles, e.g. via the same outlet as the syngas is extracted, as in more conventional systems. The gasification system further has at least one outlet for extracting the produced syngas, the at least one outlet may for example be arranged at a top portion of the gasification chamber. The top portion is to be understood in the context of the present application as a top-most portion of the upper section.

[0022] Furthermore, it can be said that the gasification chamber according to the first aspect of the present invention has two different sections, namely the upper section and the lower section. These two sections may, to some extent, be referred to as a "cold" section and a "hot" section, respectively, where volatile matters in the carbonaceous fuel are gasified in a flash pyrolysis reaction in the upper section (cold), and char is gasified in a carbon gasification reaction the lower section (hot). Moreover, by having the hot section disposed below the cold section the system is made more energy efficient since the lower section helps to maintain a desired temperature at the upper section. The gasification system is configured to maintain the residual char within the gasification chamber after the first thermo-chemical reaction in order to form a char bed at the lower section with the residual char. Thus, the residual char is kept from exiting the same outlet as the generated/produced synthesis gas by controlling the injection parameters of the injected fuel and/or the oxidant at the bottom gas-inlet. This diminishes the need for handling the often extremely hot residual char in any piping connected to the one or more outlets which reduces the cost of the gasification system.

[0023] Further, the present invention relies on gasification with very limited combustion of the carbonaceous particulate fuel, as opposed to many known prior solutions, where complete combustion is included in at least one process step. Thereby, i.e. by having a low level of combustion of the carbonaceous fuel in a gasification process, the cold gas efficiency can be increased. According to an embodiment, the particulate fuel comprises particles with a particle size of less than 3 mm and a moisture ratio of not more than 30 wt%. For example, 80 % or more of the particulate fuel comprises particles with a particle size of less than 3 mm and a moisture ratio of not more than 30 wt%. According to another embodiment, additional substance besides oxidant and particulate fuel, such as e.g. catalysts or inert substance or e.g. sand or carbon dioxide, are injected into the upper section via the at least one fuel inlet or a secondary inlet.

[0024] Even further, in accordance with an embodiment of the present invention, the oxidant injection through said at least one gas-inlet is arranged such that an injection velocity of said injected oxidant into said char bed is controlled such that a fluidization of said char bed does not disrupt a balance between the downwardly directed falling of residual char from said upper section and upwardly directed flow of gas (within the gasification chamber).

[0025] It is to be understood that the terminology "disrupt a balance between the downwardly and upwardly directed flows" is to be interpreted as, that the oxidant injection through the gas inlet at the bottom is used to control the flow balance (within the chamber) such that no residual char (which is traveling down by gravitational force within the gasification chamber towards the lower section) is pushed upwards by the upwardly directed flow of gas which is affected by the injected oxidant at the bottom portion.

[0026] In more detail, by controlling the injection velocity of the oxidant injection at the bottom portion such that the upwardly directed gas velocity in the gasification chamber is kept within e.g. an interval of 0.1 to 2.0 m/s, the risk of disrupting/destroying the (fluidized) char bed, and consequently being forced to handle the residual char together with the generated and extracted synthesis gas, is reduced. This also enables the injection of light weight carbonaceous particulate fuel, while still being able to form a (fluidizing/fluidized) char bed at the bottom from the residual char generated in the thermo-chemical process.

[0027] The term "gas velocity" is in reference to the gas traveling within the chamber, and not to the injection velocity of the oxidant, as the injection velocity is most often higher and depends on various structural details such as e.g. size and shape of the gas inlet(s) which can be varied depending on desired specifications or applications.

[0028] The gas velocity is at least partly set or limited based on the dimensions and general structure of the gasification chamber and can be regulated by the injection velocity. In other words, the gas injection velocity is controlled in order to keep the upwardly and downwardly directed flows in balance such that the bed material (residual char) of the fluidizing char bed isn't scattered upwards within the chamber. Hereby the residual char, generated from the thermo-chemical gasification/pyrolysis process in the upper section of the gasification chamber, is allowed to travel downwards toward the lower section and to form the (fluidized) char bed.

[0029] In an embodiment of the invention, the oxidant injection through said at least one gas-inlet is arranged such that a supply of oxidant into the char bed is in the range of 40-80% of a total oxidant supply into the gasification chamber. The screw-feeder may, in some embodiments, be configured to inject carbonaceous fuel with an injection velocity being less than 5 m/s.

[0030] Further, in accordance with yet another embodiment the upper section of the gasification chamber has a curved inner surface, and wherein the solid particulate carbonaceous fuel and the oxidant are (concurrently) injected into the upper section and dispersed in the gasification chamber such that a entrained flow of the synthesis gas is formed and whereby residual char is separated and allowed to travel from the upper section down towards the lower section in order to form the char bed. In more detail, in this embodiment, the gasification reactions occurs in a dense cloud of fuel particles that is fed into the gasification chamber where it forms a plume falling down towards the bottom portion of the lower section of the chamber. A plume may in the present context be understood as an elongated cloud of gas or vapour resembling a feather as it spreads from its point of origin. These types of gasification chambers are often referred to as entrained flow reactors or entrained flow gasifiers. The term "entrained flow" is in reference to a concurrent injection (or feeding) of the carbonaceous fuel particles and the oxidant, where the oxidant flow can for example act as a carry for the fuel particles. Moreover, an entrained flow gasifier is specifically suitable for use with pulverized fuel, whereby oxidant being injected together with the fuel is consumed in the first thermo-chemical reaction.

[0031] Further, in accordance with yet another embodiment of the present invention, the screw-feeder is protruding into the gasification chamber so that the fuel is evenly distributed as a plume in the gasification chamber. The screw-feeder is arranged to protrude into the gasification chamber in order to more evenly spread the (particulate) carbonaceous fuel and utilize the volume of the gasification chamber in a more efficient manner. This further increases the contact area between the carbonaceous fuel particles and the gas which enhances the thermo-chemical reactivity. The screw-feeder may for example be arranged to protrude into the gasification chamber by at least 30% of the distance from a sidewall to a central vertical axis, in other words, by at least 30% of the radius of the gasification chamber (if approximated as a cylinder).

[0032] According to yet another embodiment of the present invention the gasification chamber further comprises one or more temperature control inlets arranged through a side-wall of said gasification chamber. The temperature control inlet(s) is/are configured to inject oxidant into the gasification chamber whereby a process temperature within said gasification chamber is controlled.

[0033] This provides for an efficient and simple means for controlling the process temperature at various sections or stages of the gasification chamber, for example in order to maintain the temperature gradient (decreasing upwards) from the char bed at the lower section to the upper section. The injected gas can for example be air, steam or oxygen. The one or more temperature inlets can be spatially separated and distributed along a (vertical) length of the gasification chamber, i.e. being serially arranged in a side-wall of the gasification chamber from a top to a bottom of the gasification chamber. For example, the gasification chamber may comprise a temperature control inlet arranged at the upper section, a temperature control inlet at the lower section and a temperature control inlet at a mid section (between the upper section and the lower section). The temperature control inlets are preferably individually controllable in terms of injection rates for the injected gas.

[0034] The temperature control inlets may for example be configured to maintain a temperature at the upper section of the gasification chamber in the range of 800°C to 1100°C, and to maintain a temperature of the (at least partly fluidized) char bed at the lower section in the range of 1200°C to 1500°C, in order to ensure that the first thermo-chemical reaction is a flash pyrolysis reaction and the second thermo-chemical reaction is a carbon gasification reaction.

[0035] Moreover, in yet another embodiment the fuel is pre-heated by a pre-heating arrangement whereby the needed residence time of the particulate carbonaceous fuel within the gasification chamber can be reduced.

[0036] Further, preheating may be accomplished by using the fuel inlet, to inject a fuel together with an oxidant in order to provide for an exothermic reaction between the fuel and the oxidant. This exothermic reaction will thus pre-heat the fuel before the injecting into the gasification chamber. An optional alternative for pre-heating is to pre-heat the particulate carbonaceous fuel and the oxidant in the screw-feeder, i.e. before it is injected into the upper section via the fuel-inlet.

[0037] The gasification system further comprises a perforated grate located at said bottom portion, in order to facilitate extraction of residual ashes.

[0038] According to another aspect of the present invention, there is provided a method for gasifying carbonaceous material, where the method comprises:

providing a gasification chamber having an upper section, a lower section and a screw-feeder arranged at a predefined distance from the bottom portion, the predefined distance being at least 30% of a vertical extension of the gasification chamber;

injecting, by means of the screw-feeder, a carbonaceous solid fuel being less than 10 mm in diameter (and oxidant in some embodiments) into the upper section of the gasification chamber whereby synthesis gas and residual char is generated in a first thermo-chemical reaction occurring during a downwardly directed falling of the carbonaceous fuel towards a bottom portion of the lower section;

forming a char bed in the bottom portion of the lower section from the residual char being generated in the first thermo-chemical reaction;

injecting oxidant into said char bed via at least one gas inlet at the bottom portion in order to enable a second thermo-chemical reaction whereby the residual char is converted to synthesis gas, wherein at least one injection parameter of the oxidant via the at least one gas inlet is controlled such that a residence time of the downward falling carbonaceous solid fuel is at least 1 second.

[0039] With this aspect of the invention, similar advantages and preferred features are present as in the previously discussed first aspect of the invention, and vice versa.

[0040] The injection paramters of the oxidant via the one or more gas inlets may for example be injection velocity and/or an injection amount/supply in reference to the total oxidant supply into the gasification chamber. For example, the supply of oxidant via the at least one gas inlet into the char bed may be in the range of 40 - 80 % of a total oxidant supply into the gasification chamber or the injection velocity may be controlled such that an upwardly directed gas velocity within the gasification chamber is in the range of 0.1 - 2.0 m/s.

[0041] Furthermore, in accordance with an embodiment of the invention, the method further comprises:

maintaining a temperature at the upper section of the gasification chamber in the range of 800°C to 1100°C; and

maintaining a temperature of the char bed at the lower section of the gasification chamber in the range of 1200°C to 1500°C.

[0042] In other words, the gasification chamber will have two zones or section with different temperatures, whereby an efficient gasification method with increased energy output can be achieved. The temperature in the upper section may for example over 900°C, and the temperature in the lower section and more specifically in the char bed may be over 1300°C. By controlling/maintaining the temperatures accordingly the gasification system can be configured such that the first thermo-chemical reaction is a flash pyrolysis reaction and the second thermochemical reaction is a carbon gasification reaction.

[0043] These and other features and advantages of the present invention will in the following be further clarified with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0044] For exemplifying purposes, the invention will be described in closer detail in the following with reference to embodiments thereof illustrated in the attached drawings, wherein:

Fig. 1 is a schematic illustration of a gasification system in accordance with an embodiment of the present invention;

Fig. 2 illustrates a cross-sectional view of a gasification system in accordance with an embodiment of the invention;

Fig. 3 is a schematic flow chart illustration a method for gasifying carbonaceous material in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0045] In the following detailed description, preferred embodiments of the present invention will be described. However, it is to be understood that features of the different embodiments are exchangeable between the embodiments and may be combined in different ways, unless anything else is specifically indicated. Even though in the following description, numerous specific details are set forth to provide a more thorough understanding of the present invention, it will be apparent to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well known constructions or functions are not described in detail, so as not to obscure the present invention.

[0046] In Fig. 1 a schematic illustration of a gasification system 1 is provided. The gasification system includes a gasification chamber 2, shown in a cross-sectional view where the cross-section is taken in a vertical plane including a longitudinal vertical axis 101. Furthermore, the gasification chamber 2 has an inner and an outer wall, and the chamber may for example be made of a ceramic material.

[0047] The gasification chamber 2 has an upper section 3 and a lower section 4 and a screw-feeder or screw-feeding device 8. The screw feeding device is arranged to inject and disperse a carbonaceous solid fuel with a particle size of less than 10 mm into the upper section 3 whereby synthesis gas and residual char is generated by a first thermo-chemical reaction occurring during a downwardly directed falling of the particulate carbonaceous fuel towards a bottom portion of said lower section 3. The first thermo-chemical reaction is preferably a flash pyrolysis reaction. Also, the injection velocity of the carbonaceous fuel is preferably less than 5 m/s.

[0048] The screw-feeder 8 may also be configured to inject oxidant into the gasification chamber 2, however, oxidant may be injected into the gasification chamber via one or more separate oxidant inlets. Moreover, the screw-feeder 8 can include a preheating arrangement (not shown) in order to preheat the carbonaceous fuel before it is injected into the gasification chamber 2. The preheating arrangement can for example include a fluid channel extending through the screw-feeder 8, and where a hot gas is allowed to flow through the fluid channel so that the particulate carbonaceous fuel is preheated while it is travels helically through the screw-feeder 8.

[0049] Further, the gasification system 1 has a char bed 12 disposed in the lower section 4. The char bed 12 is formed by residual char generated in the first thermo-chemical reaction, which travels downwards due to gravitational force towards the bottom portion 5. The bottom portion 5 can for example be said to be defined by a bottom surface upon which the residual char generated by the first thermo-chemical reaction is collected. Moreover, there is at least one gas inlet 17 at the bottom portion 5 through which oxidant can be injected into the char bed 12 in order to create a second thermo-chemical reaction whereby synthesis gas is generated from the residual char. The second thermo-chemical reaction is preferably a carbon gasification reaction. Thus, synthesis gas is generated by two different thermo-chemical reactions at different sections of the gasification chamber 2, which increases the overall output of synthesis gas and thereby the efficiency of the gasification system 1. The two sections 3, 4 are preferably part of one single vessel or container and consequently the two thermo-chemical reactions occur within the same vessel or container.

[0050] The bottom portion 5 further includes a perforated grate 15 on top which supports the char bed 12, and which is used to extract residual ashes. In other words, there gasification chamber 2 comprises an outlet at the bottom portion through which residual ash particles may exit the gasification chamber. The outlet is at least partly blocked by the perforated grate 15 in order to support the formation of the char bed 12, however, the perforated grate 15 may for example be movable (by an operator or an actuator) in order to extract any residual ash particles collected at the bottom of the char bed 12.

[0051] Even further, the screw-feeder is arranged at a predefined distance 23 from the bottom portion 5, the predefined distance 23 being at least 30% of a vertical extension of the gasification chamber. Hereby the dispersed carbonaceous particles have a long enough residence time in order to travel through different reaction zones within the gasification chamber 2, whereby a complete conversion of the carbonaceous fuel to synthesis gas can be achieved. In other words, the gasification system allows for controlled falling of fine fraction carbonaceous fuel from the upper section 3 to the lower section 4 of the gasification chamber 2, so that a first thermo-chemical reaction (flash pyrolysis) of the fuel can be achieved. The gravitational falling also provides an advantageous condition as it means that the fuel is dispersed in the hot gas of the gasification. Such dispersion increases the contact area between the fuel and the gas which enhances the thermo-chemical reactivity. The residence time of the carbonaceous fuel during the downwardly directed falling (i.e. before it is converted to synthesis gas and residual char or reaches the char bed) is preferably at least one second and more preferably at least two seconds.

[0052] Yet further, one or more injection parameters of the oxidant injection into the char bed 12 can be controlled so that a fluidization of the char bed 12 does not disrupt a balance between the downwardly directed falling of residual char from the upper section and upwardly directed flow of the injected oxidant. In more detail this can be construed as the injection of oxidant is controlled so that it does negatively affect the falling residual char (and possibly even the particulate carbonaceous fuel) and consequently inhibiting the desired "falling" through the different reaction zones. The injection parameters may for example be injection velocity, injection angle or the amount of injected oxidant in reference to the total oxidant supply into the gasification chamber. In an example embodiment the oxidant injection through the at least one gas-inlet 17 is arranged such that an upward gas velocity in the gasification chamber is in the range of 0.1 m/s to 2.0 m/s.

[0053] Moreover, the gasification chamber 2 may be arranged with a set of temperature control inlets 24. The temperature control inlets/oxidant inlets 24 are preferably spatially separated and distributed along a length (elongated axis 101) of the gasification chamber 2. A set in the present context can be one or more. The temperature control inlets 24 are configured to inject gas (such as e.g. air, steam or oxygen.) into the gasification chamber in order to control the temperature within the gasification chamber 2 at various sections. By having a plurality of temperature control inlets 24 a temperature gradient can be formed within the gasification chamber 2, for example going from a highest temperature in the lower section 4 to a lowest temperature in the upper section 3. The oxidant injection into the gasification chamber 2 is preferably arranged such that a predefined temperature in the range of 800°C to 1100°C is maintained at the upper section 3, and a predefined temperature in the range of 1200°C to 1500°C is maintained at the lower section 4. This will aid to ensure an optimized path through different reaction zones for the carbonaceous fuel.

[0054] The oxidant injection through the one or more gas-inlets 17 may be arranged so that a supply of oxidant into the char bed is in the range of 40-80% of a total oxidant supply into the gasification chamber. In other words, the ratio of oxidant injected via the one or more gas-inlets 17 at the bottom portion in refrence to the total oxidant injection (via e.g. the screw-feeder 8 and the temperature control inlets 24) is kept at 40-80% in order to ensure favourable conditions in terms of process temperatures different sections of the gasification chamber 2, fluidization of the char bed 12, residence time for the downwardly falling carbonacous fuel, etc.

[0055] Fig. 2 illustrates a cross-sectional top-view view of the gasification chamber 2 from Fig. 1, taken along line A-A'. The illustration shows an arrangement where the screw feeder 8 is protruding into the gasification chamber by a predefined distance P. The predefined distance P is preferably at least 30% of the radius d of the gasification chamber. In other words, the tip of the screw-feeder extends towards a central vertical axis (101 in Fig. 1) of the gasification chamber. By arranging the screw-feeder 8 as such, the particulate carbonaceous fuel 19 can be evenly spread within the gasification chamber, utilizing a higher ratio of the available volume and thereby increasing the efficiency. In more detail, the dispersion increases the contact area between the fuel and the gas (oxidant) which enhances the thermo-chemical reactivity.

[0056] Fig. 3 illustrates a schematic flow chart describing a method 300 for gasifying carbonaceous material in accordance with an embodiment of the present invention. The method 300 comprises a step of providing 301 a gasification chamber having an upper section, a lower section and a screw-feeder arranged at a predefined distance (23 in Fig. 1) from the bottom portion. The predefined distance is at least 30% of a vertical extension of the gasification chamber.

[0057] Next, a carbonaceous solid fuel being less than 10 mm in diameter is injected 302 by means of the screw-feeder, into said upper section of the gasification chamber. Hereby, synthesis gas and residual char is generated in a first thermo-chemical reaction occurring during a downwardly directed falling of the carbonaceous fuel towards a bottom portion of the lower section. The step of injecting 302 the carbonaceous solid fuel may in some embodiments also include injecting oxidant into the gasification chamber (separately or concurrently). Next, the method 300 includes a step of forming 303 a char bed in the bottom portion of said lower section from the residual char being generated in said first thermo-chemical reaction.

[0058] Yet further, oxidant is injected 304 into the char bed via the one or more gas inlets at the bottom portion. This enables enable a second thermo-chemical reaction whereby said residual char is converted to synthesis gas. Moreover, at least one injection parameters is controlled such that a residence time of the downward falling carbonaceous solid fuel is at least 1 second, more preferably at least 2 seconds. The injection parameters may for example be injection velocity, injection angle, amount of injected oxidant in reference to the total oxidant supply into the gasification chamber, etc.

[0059] The method may further comprise maintaining a temperature within the gasification chamber at the upper section in the range of 800°C - 1100°C, preferably in the range of 850°C - 1000°C and more preferably in the range of 900°C - 950°C. Moreover, the method can also comprise a step of maintaining a temperature of the char bed at the lower section of the gasification chamber in the range of 1200°C - 1500°C preferably in the range of 1250°C - 1400°C and more preferably in the range of 1300°C - 1350°C. The temperature within the different sections or portions of the gasification chamber can for example be maintained (or controlled) by injection of oxidant into the gasification chamber via a set of temperature control inlets and/or the one or more gas inlets at the bottom portion.

[0060] The invention has now been described with reference to specific embodiments. However, several variations of the gasification system are feasible. For example, injections velocities may be varied within the intervals given in order to suit specific applications and carbonaceous fuel-types, as already exemplified. Such and other obvious modifications must be considered to be within the scope of the present invention, as it is defined by the appended claims. It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting to the claim. The word "comprising" does not exclude the presence of other elements or steps than those listed in the claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

Claims

1. A gasification system (1) comprising:

   a gasification chamber (2) having an upper section (3) and a lower section (4);
   at least one screw-feeder (8) for injecting and dispersing a carbonaceous solid fuel with a particle size of less than 10 mm into said upper section whereby synthesis gas and residual char is generated by a first thermo-chemical reaction occurring during a downwardly directed falling of said carbonaceous fuel towards a bottom portion (5) of said lower section;
   a char bed disposed in said lower section, said char bed being formed by residual char generated in said first thermo-chemical reaction;
   at least one gas-inlet (17) at a bottom portion of said lower section for injecting oxidant into said char bed whereby synthesis gas is generated by a second thermo-chemical reaction from said residual char;
   wherein said at least one screw-feeder is arranged at a predefined distance (23) from the bottom portion, wherein said predefined distance is at least 30% of a vertical extension of the gasification chamber, wherein the oxidant injection through said at least one gas-inlet is arranged such that an injection velocity of said injected oxidant into said char bed is controlled such that a fluidization of said char bed does not disrupt a balance between the downwardly directed falling of residual char from said upper section and upwardly directed flow of gas, wherein said system comprises a perforated grate (15) located at said bottom portion, in order to support the char bed and to extract residual ashes.

2. The gasification system according to claim 1, wherein said gasification system is configured such that

said first thermo-chemical reaction is a flash pyrolysis reaction and said second thermo-chemical reaction is a carbon gasification reaction.

3. The gasification system according to any one of the claims 1-2, wherein the oxidant injection through said at least one gas-inlet is arranged such that a supply of oxidant into the char bed is in the range of 40-80% of a total oxidant supply into the gasification chamber.

4. The gasification system according to any one of claims 1-3, wherein said screw-feeder is protruding into the gasification chamber so that the fuel is evenly distributed as a plume in the gasification chamber.

5. The gasification system according to any one of claims 1-4, wherein said screw-feeder injects the carbonaceous fuel with an injection velocity being less than 5 m/s.

6. The gasification system according to any one of claims 1-5, wherein said gasification chamber further comprises at least one temperature control inlet (24) arranged through a side-wall of said gasification chamber, wherein said temperature control inlet is configured to inject oxidant into the gasification chamber whereby a process temperature within said gasification chamber is controlled.

7. The gasification system according to any one of claims 1-6, wherein the gasification chamber is provided with a preheating arrangement which is preheating said fuel before it is injected, via said screw-feeder, into the gasification chamber.

8. The gasification system according to any one of the claims 1-7, wherein the residence time of the fuel during said downward falling is at least 1 second.

9. A method for gasifying carbonaceous material comprising:

providing a gasification chamber having an upper section, a lower section and a screw-feeder arranged at a predefined distance from the bottom portion, said predefined distance being at least 30% of a vertical extension of the gasification chamber;
injecting, by means of said screw-feeder, a carbonaceous solid fuel being less than 10 mm in diameter into said upper section of the gasification chamber whereby synthesis gas and residual char is generated in a first thermo-chemical reaction occurring during a downwardly directed falling of the carbonaceous fuel towards a bottom portion of said lower section;
forming a char bed in the bottom portion of said lower section from the residual char being generated in said first thermo-chemical reaction;
injecting oxidant into said char bed via at least one gas inlet at said bottom portion in order to enable a second thermo-chemical reaction whereby said residual char is converted to synthesis gas, wherein at least one injection parameter of said oxidant via said at least one gas inlet is controlled such that a residence time of said downward falling carbonaceous solid fuel is at least 1 second, wherein the oxidant injection through said at least one gas-inlet is arranged such that an injection velocity of said injected oxidant into said char bed is controlled such that a fluidization of said char bed does not disrupt a balance between the downwardly directed falling of residual char from said upper section and upwardly directed flow of gas.

10. The method according to claim 9, further comprising:

maintaining a temperature at said upper section of the gasification chamber in the range of 800°C to 1100°C; and
maintaining a temperature of said char bed at said lower section of the gasification chamber in the range of 1200°C to 1500°C.

Patentansprüche

1. Vergasungsanlage (1), die Folgendes umfasst:

eine Vergasungskammer (2), die eine obere Sektion (3) und eine untere Sektion (4) aufweist, wenigstens einen Schneckenaufgeber (8) zum Einpressen und Verteilen eines kohlenstoffhaltigen festen Brennstoffs mit einer Teilchengröße von weniger als 10 mm in die obere Sektion, wodurch Synthesegas und
Restkohle durch eine erste thermochemische Reaktion erzeugt werden, die während eines nach unten gerichteten Fallens des kohlenstoffhaltigen Brennstoffs zu einem Sohlenabschnitt (5) der unteren Sektion hin stattfindet,
ein Kohlebett, das in der unteren Sektion angeordnet ist, wobei das Kohlebett durch Restkohle gebildet wird, die in der ersten thermochemischen Reaktion erzeugt wird,
wenigstens einen Gaseinlass (17) an einem Sohlenabschnitt der unteren Sektion zum Einpressen von Oxidationsmittel in das Kohlebett, wodurch Synthesegas durch eine zweite thermochemische Reaktion aus der Restkohle erzeugt wird,
wobei der wenigstens eine Schneckenaufgeber bei einem vorbestimmten Abstand (23) von dem Sohlenabschnitt angeordnet ist, wobei der vor-

bestimmte Abstand wenigstens 30 % einer vertikalen Ausdehnung der Vergasungskammer beträgt, wobei das Oxidationsmittel-Einpressen durch den wenigstens einen Gaseinlass derart angeordnet ist, dass eine Einpressgeschwindigkeit des eingepressten Oxidationsmittels in das Kohlebett derart gesteuert wird, dass ein Fluidisieren des Kohlebetts ein Gleichgewicht zwischen dem nach unten gerichteten Fallen von Restkohle aus dem oberen Abschnitt und dem nach oben gerichteten Gasstrom nicht zerstört, wobei die Anlage einen perforierten Rost (15) umfasst, der an dem Sohlenabschnitt angeordnet ist, um das Kohlebett zu tragen und um Restaschen abzutrennen.

2. Vergasungsanlage nach Anspruch 1, wobei die Vergasungsanlage derart konfiguriert ist, dass die erste thermochemische Reaktion eine Flash-Pyrolysereaktion ist und die zweite thermochemische Reaktion eine Kohlenstoff-Vergasungsreaktion ist.

3. Vergasungsanlage nach einem der Ansprüche 1 bis 2, wobei das Oxidationsmittel-Einpressen durch den wenigstens einen Gaseinlass derart angeordnet ist, dass eine Zufuhr von Oxidationsmittel in das Kohlebett in dem Bereich von 40 bis 80 % einer gesamten Oxidationsmittelzufuhr in die Vergasungskammer liegt.

4. Vergasungsanlage nach einem der Ansprüche 1 bis 3, wobei der Schneckenaufgeber so in die Vergasungskammer vorspringt, dass der Brennstoff als eine Fahne in der Vergasungskammer verteilt wird.

5. Vergasungsanlage nach einem der Ansprüche 1 bis 4, wobei der Schneckenaufgeber den kohlenstoffhaltigen Brennstoff mit einer Einpressgeschwindigkeit einpresst, die geringer als 5 m/s ist.

6. Vergasungsanlage nach einem der Ansprüche 1 bis 5, wobei die Vergasungskammer ferner wenigstens einen Temperatursteuerungseinlass (24) umfasst, der durch eine Seitenwand der Vergasungskammer angeordnet ist, wobei der Temperatursteuerungseinlass dafür konfiguriert ist, Oxidationsmittel in die Vergasungskammer einzupressen, wodurch eine Prozesstemperatur innerhalb der Vergasungskammer gesteuert wird.

7. Vergasungsanlage nach einem der Ansprüche 1 bis 6, wobei die Vergasungskammer mit einer Vorheizungsanordnung versehen ist, die den Brennstoff vorheizt, bevor er, über den Schneckenaufgeber, in die Vergasungskammer eingepresst wird.

8. Vergasungsanlage nach einem der Ansprüche 1 bis 7, wobei die Verweildauer des Brennstoffs während des Fallens nach unten wenigstens 1 Sekunde beträgt.

9. Verfahren zum Vergasen von kohlenstoffhaltigem Material, wobei das Verfahren Folgendes umfasst:

Bereitstellen einer Vergasungskammer, die eine obere Sektion, eine untere Sektion und einen Schneckenaufgeber, der bei einem vorbestimmten Abstand von dem Sohlenabschnitt angeordnet ist, aufweist, wobei der vorbestimmte Abstand wenigstens 30 % einer vertikalen Ausdehnung der Vergasungskammer beträgt,
Einpressen, mit Hilfe des Schneckenaufgebers, eines kohlenstoffhaltigen festen Brennstoffs, der im Durchmesser weniger als 10 mm aufweist, in die obere Sektion der Vergasungskammer, wodurch Synthesegas und Restkohle in einer ersten thermochemischen Reaktion erzeugt werden, die während eines nach unten gerichteten Fallens des kohlenstoffhaltigen Brennstoffs zu einem Sohlenabschnitt der unteren Sektion hin stattfindet,
Bilden eines Kohlebetts in dem Sohlenabschnitt der unteren Sektion aus der Restkohle, die in der ersten thermochemischen Reaktion erzeugt wird, Einpressen eines Oxidationsmittels in das Kohlebett über wenigstens einen Gaseinlass an dem Sohlenabschnitt, um eine zweite thermochemische Reaktion zu ermöglichen, wodurch die Restkohle zu Synthesegas umgewandelt wird, wobei wenigstens ein Einpressparameter des Oxidationsmittels über den wenigstens einen Gaseinlass derart gesteuert wird, dass eine Verweildauer des nach unten fallenden kohlenstoffhaltigen Brennstoffs wenigstens 1 Sekunde beträgt, wobei das Oxidationsmittel-Einpressen durch den wenigstens einen Gaseinlass derart angeordnet ist, dass eine Einpressgeschwindigkeit des eingepressten Oxidationsmittels in das Kohlebett derart gesteuert wird, dass ein Fluidisieren des Kohlebetts ein Gleichgewicht zwischen dem nach unten gerichteten Fallen von Restkohle aus dem oberen Abschnitt und dem nach oben gerichteten Gasstrom nicht zerstört.

10. Verfahren nach Anspruch 9, das ferner Folgendes umfasst:
Aufrechterhalten einer Temperatur an der oberen Sektion der Vergasungskammer in dem Bereich von 800°C bis 1100°C und Aufrechterhalten einer Temperatur des Kohlebetts an der unteren Sektion der Vergasungskammer in dem Bereich von 1200°C bis 1500°C.

Revendications

1. Système de gazéification (1) comprenant :

une chambre de gazéification (2) ayant une section supérieure (3) et une section inférieure (4) ;
au moins un distributeur à vis (8) pour injecter et disperser un combustible solide carboné avec une taille de particule inférieure à 10 mm jusque dans ladite section supérieure, tandis que du gaz de synthèse et du résidu de carbonisation est généré par une première réaction thermochimique se produisant pendant une chute dirigée vers le bas dudit combustible carboné en direction d'une partie de fond (5) de ladite section inférieure ;
un lit de charbon disposé dans ladite section inférieure, ledit lit de charbon étant formé par du résidu de carbonisation généré dans ladite première réaction thermochimique ;
au moins une entrée de gaz (17) à une partie de fond de ladite section inférieure pour injecter de l'oxydant dans ledit lit de charbon, tandis que du gaz de synthèse est généré par une seconde réaction thermochimique à partir dudit résidu de carbonisation ;
dans lequel ledit au moins un distributeur à vis est agencé à une distance prédéfinie (23) de la partie de fond, dans lequel ladite distance prédéfinie est au moins de 30 % d'une extension verticale de la chambre de gazéification,
dans lequel l'injection d'oxydant à travers ladite au moins une entrée de gaz est agencée de telle façon qu'une vitesse d'injection dudit oxydant injecté jusque dans ledit lit de charbon est commandée de telle façon qu'une fluidisation dudit lit de charbon n'interrompt pas un équilibre entre la chute dirigée vers le bas de résidu de carbonisation à partir de ladite section supérieure et le flux de gaz dirigé vers le haut, dans lequel ledit système comprend une grille perforée (15) située sur ladite partie de fond, afin de supporter le lit de charbon et d'extraire les cendres résiduelles.

2. Système de gazéification selon la revendication 1, dans lequel ledit système de gazéification est configuré de telle façon que ladite première réaction thermochimique est une réaction à pyrolyse flash et ladite seconde réaction thermochimique est une réaction de gazéification carbonique.

3. Système de gazéification selon l'une quelconque des revendications 1-2, dans lequel l'injection d'oxydant à travers ladite au moins une entrée de gaz est agencée de telle façon d'une alimentation d'oxydant dans le lit de charbon est située dans la plage de 40-80 % d'une alimentation d'oxydant totale dans la chambre de gazéification.

4. Système de gazéification selon l'une quelconque des revendications 1-3, dans lequel ledit distributeur à vis fait saillie jusque dans la chambre de gazéification de façon à ce que le combustible soit distribué de manière régulière en tant qu'un panache dans la chambre de gazéification.

5. Système de gazéification selon l'une quelconque des revendications 1-4, dans lequel ledit distributeur à vis injecte le combustible carboné avec une vitesse d'injection étant inférieure à 5 m/s.

6. Système de gazéification selon l'une quelconque des revendications 1-5, dans lequel ladite chambre de gazéification comprend en outre au moins une entrée de commande de température (24) agencée à travers une paroi latérale de ladite chambre de gazéification, dans lequel ladite entrée de commande de température est configurée pour injecter de l'oxydant jusque dans la chambre de gazéification, tandis qu'une température de procédé à l'intérieur de ladite chambre de gazéification est commandée.

7. Système de gazéification selon l'une quelconque des revendications 1- 6, dans lequel la chambre de gazéification est dotée d'un agencement de préchauffage qui préchauffe ledit combustible avant qu'il ne soit injecté, par le biais dudit distributeur à vis, jusque dans la chambre de gazéification.

8. Système de gazéification selon l'une quelconque des revendications 1-7, dans lequel le temps de séjour du combustible pendant ladite chute vers le bas est d'au moins 1 seconde.

9. Procédé de gazéification de matériau carboné comprenant :

de fournir une chambre de gazéification ayant une section supérieure, une section inférieure et un distributeur à vis agencé à une distance prédéfinie depuis la partie de fond, ladite distance prédéfinie étant au moins de 30 % d'une extension verticale de la chambre de gazéification ;
d'injecter, au moyen dudit distributeur à vis, un combustible solide carboné étant inférieur à 10 mm de diamètre jusque dans ladite section supérieure de la chambre de gazéification, tandis que du gaz de synthèse et du résidu de carbonisation est généré dans une première réaction thermochimique se produisant pendant une chute dirigée vers le bas du combustible carboné en direction d'une partie de fond de ladite section inférieure ;
de former un lit de charbon dans la partie de

fond de ladite section inférieure à partir du résidu de carbonisation généré dans ladite première réaction thermochimique ;
d'injecter de l'oxydant dans ledit lit de charbon par le biais d'au moins une entrée de gaz sur ladite partie de fond afin de permettre une seconde réaction thermochimique, tandis que ledit résidu de carbonisation est converti en gaz de synthèse, dans lequel au moins un paramètre d'injection dudit oxydant par le biais de ladite au moins une entrée de gaz est commandé de telle façon qu'un temps de séjour dudit combustible solide carbonique chutant vers le bas est d'au moins 1 seconde, dans lequel l'injection d'oxydant à travers ladite au moins une entrée de gaz est agencée de telle façon qu'une vitesse d'injection dudit oxydant injecté jusque dans ledit lit de charbon est commandée de telle façon qu'une fluidisation dudit lit de charbon n'interrompt pas un équilibre entre la chute dirigée vers le bas de résidu de carbonisation à partir de ladite section supérieure et le flux de gaz dirigé vers le haut.

10. Procédé selon la revendication 9, comprenant en outre :

de maintenir une température à ladite section supérieure de la chambre de gazéification dans la plage de 800°C à 1100°C ; et
de maintenir une température dudit lit de charbon à ladite section inférieure de la chambre de gazéification dans la plage de 1200°C à 1500°C.

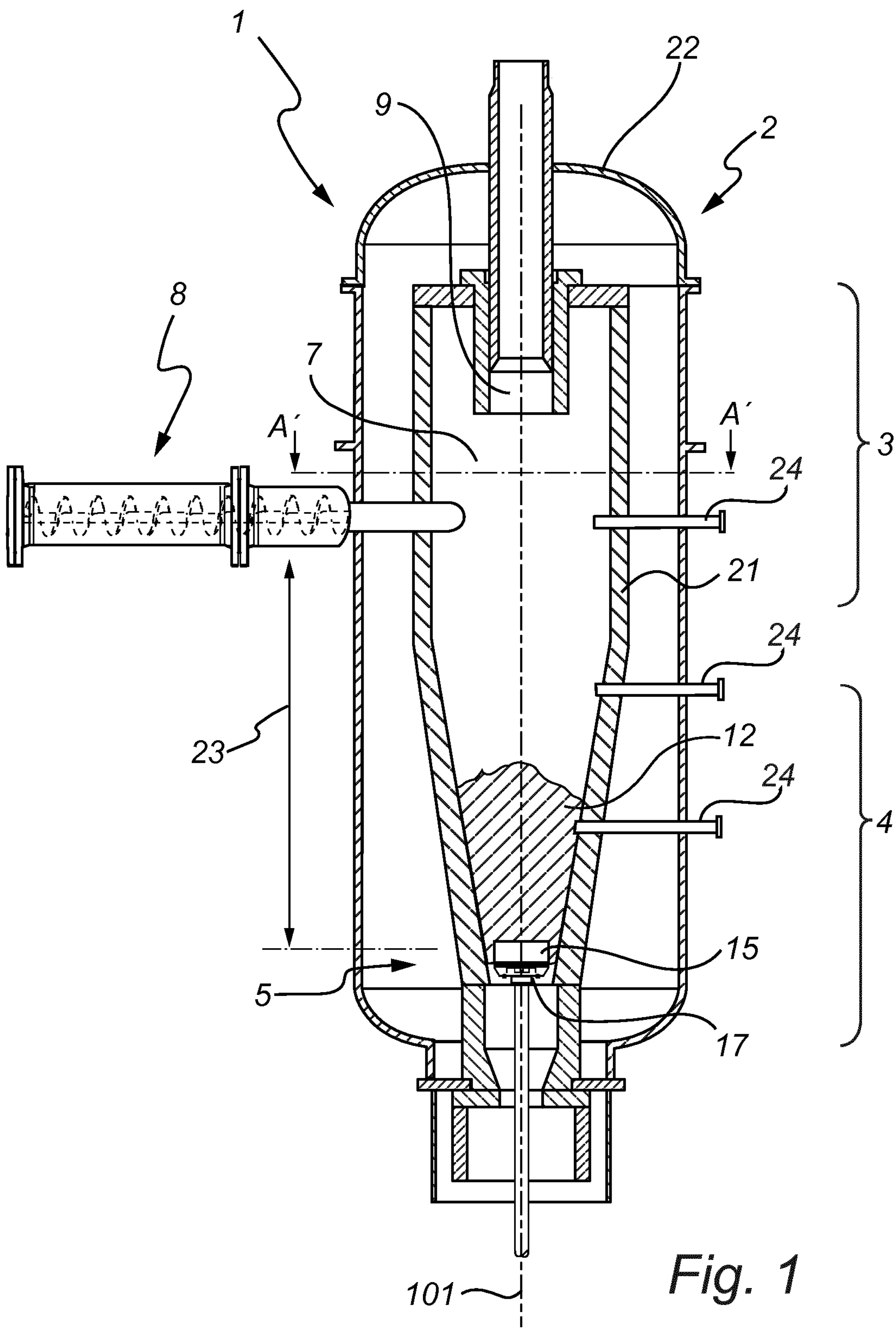
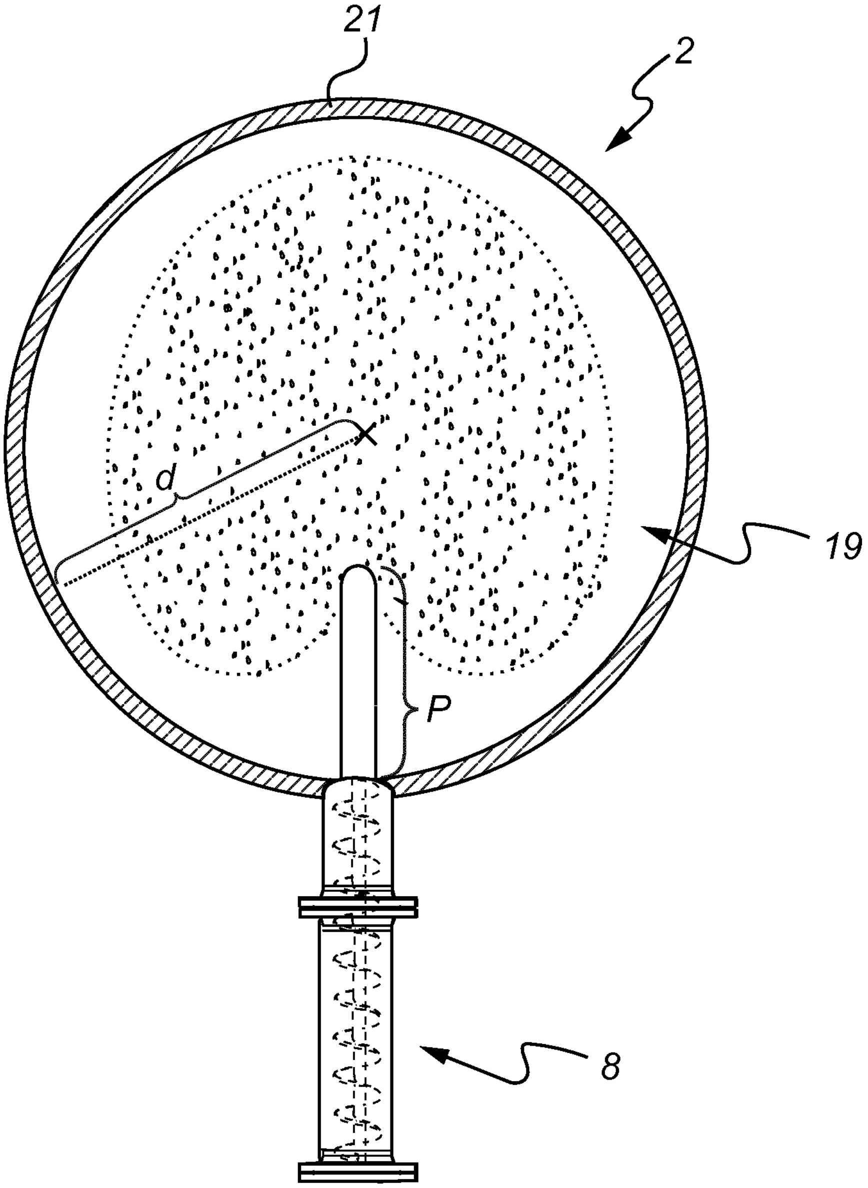


Fig. 1


21
2
d
19
P
8

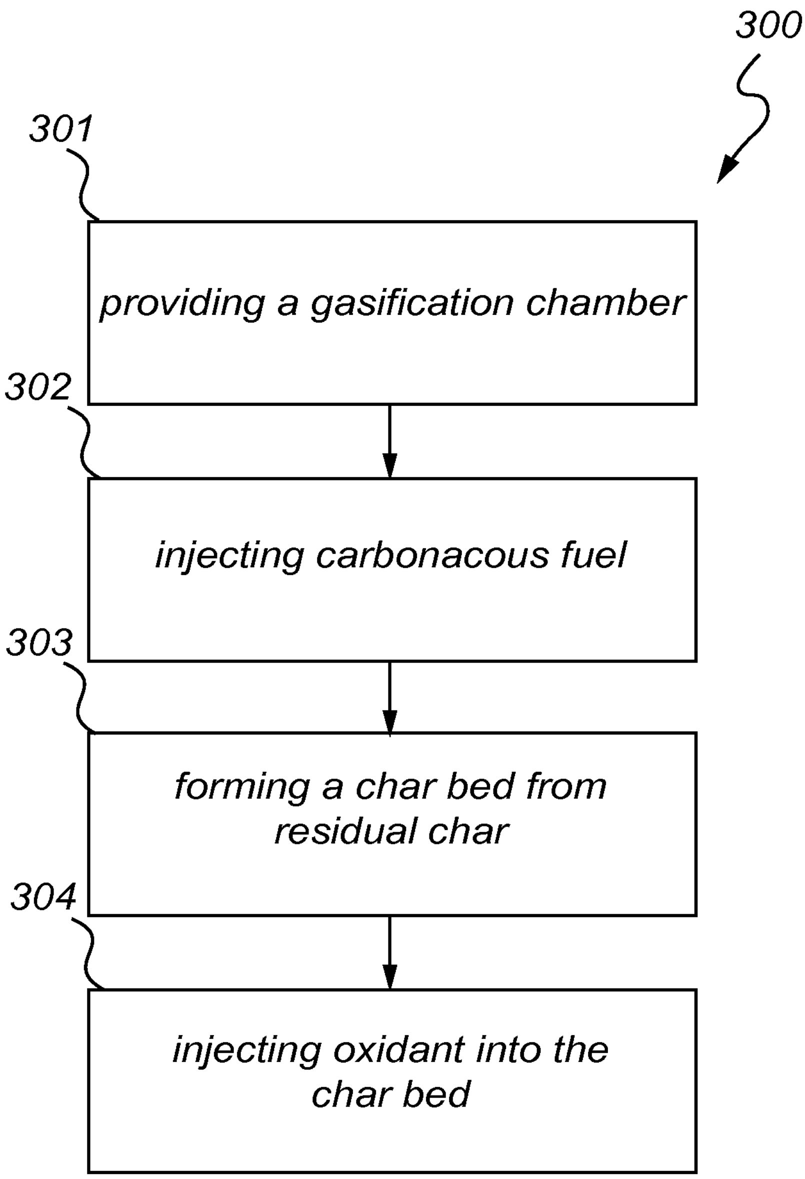

300
301
providing a gasification chamber
302
injecting carbonacous fuel
303
forming a char bed from residual char
304
injecting oxidant into the char bed

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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