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(54) **METHOD AND APPARATUS FOR TREATING A SYNGAS**

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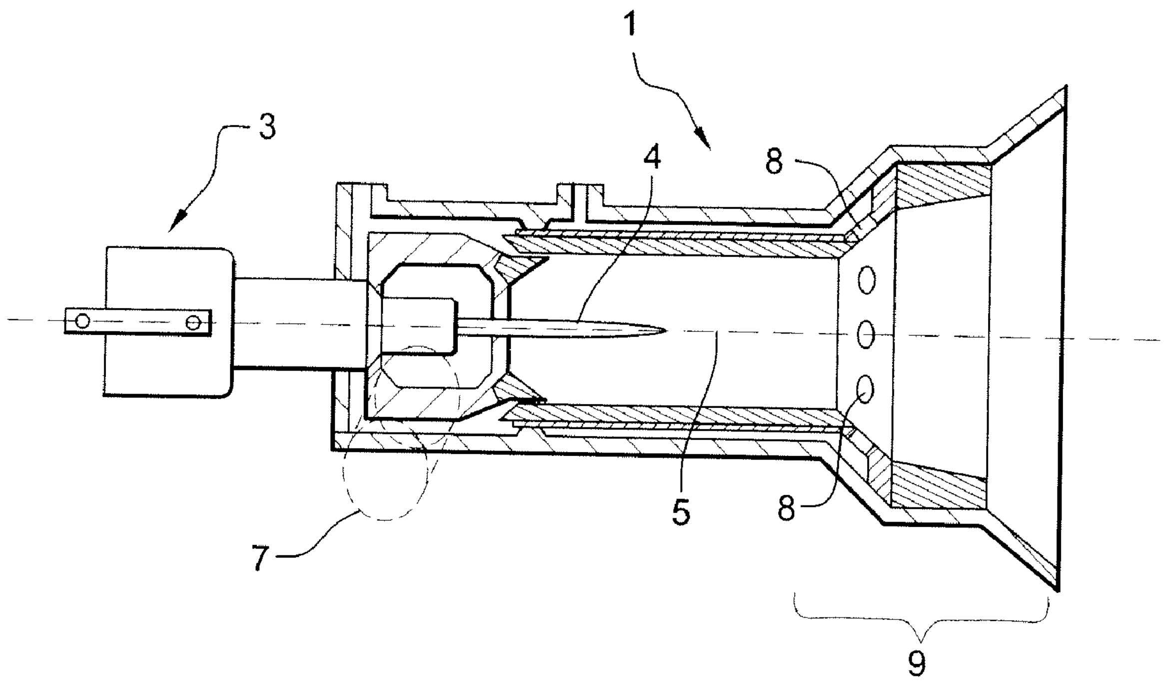
(57) **ABSTRACT**

Treating a synthesis gas includes generating a plasma jet from a non-transferred arc torch having a main axis, the jet having a propagation axis that is substantially collinear with the main axis of the torch. The plasma torch is mounted on a feed enclosure. The syngas is received at an inlet port of the feed enclosure, the inlet port being downstream from he plasma torch and feeding the syngas so the flow encounters the plasma jet to mix the syngas and plasma jet. The mixture is propagated in an elongate reactor placed downstream from the inlet port to convert the syngas into an outlet gas. The reactor is in communication in its upstream portion with the feed enclosure and has a longitudinal axis that is substantially collinear with the propagation axis of the plasma jet. The outlet gas is extracted via an outlet port.



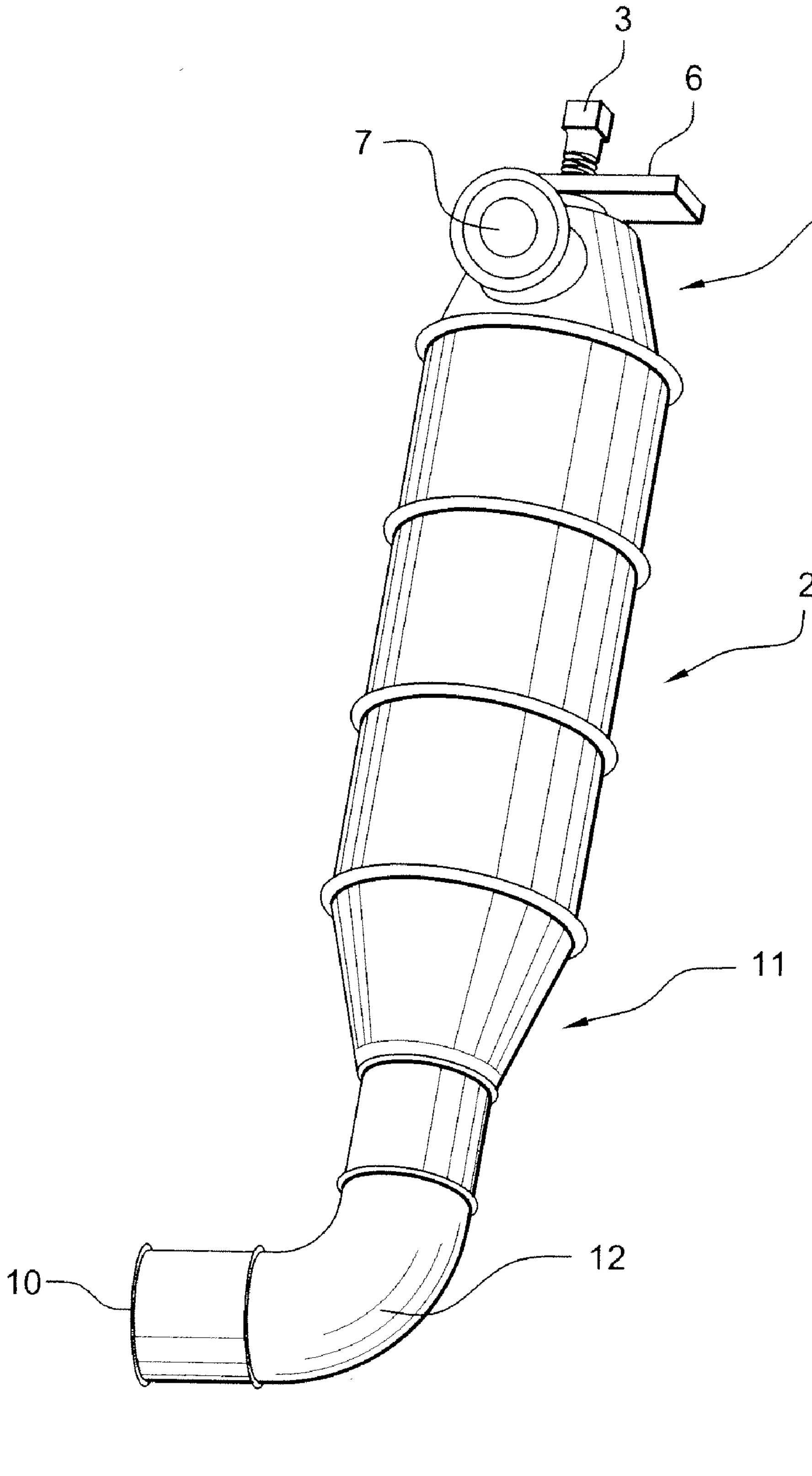


Fig. 1

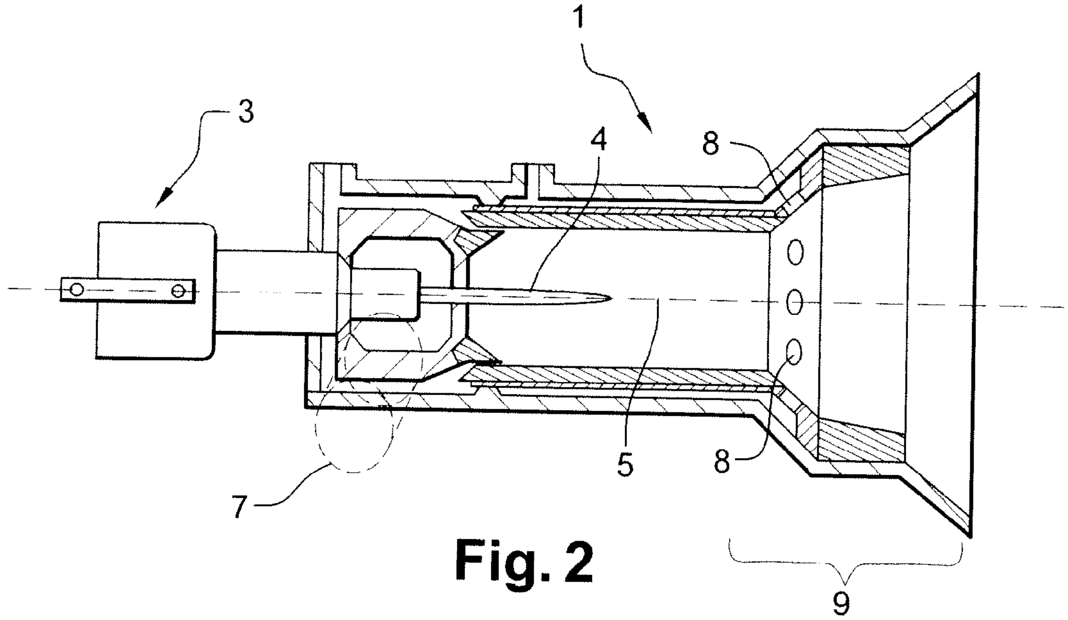


Fig. 2

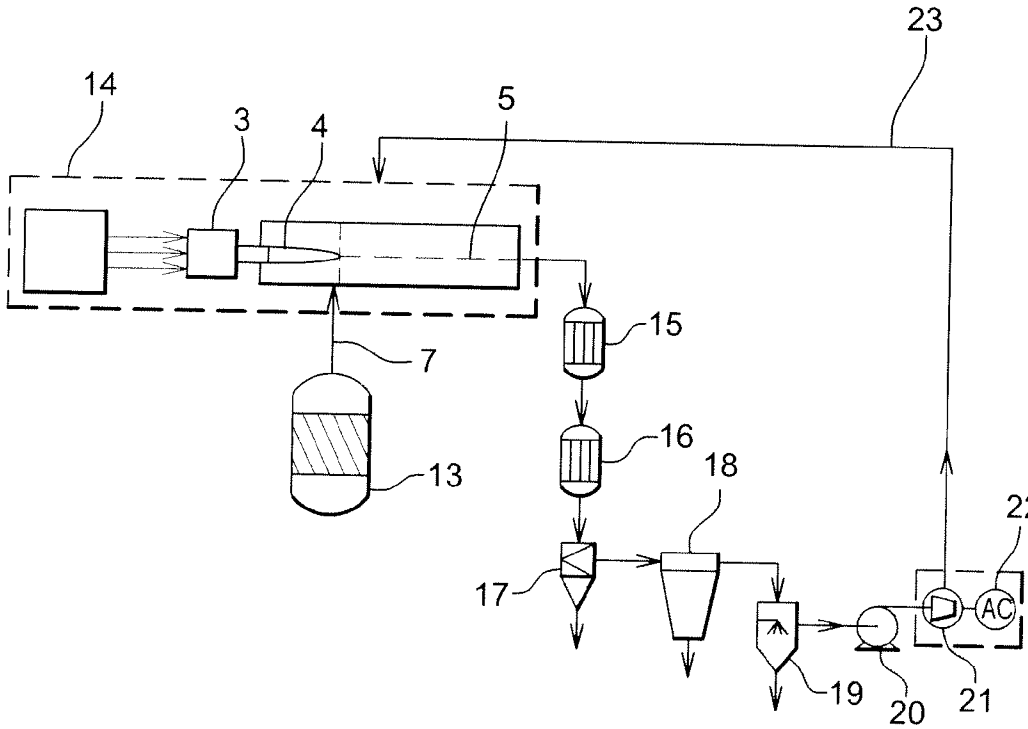


Fig. 3

METHOD AND APPARATUS FOR TREATING A SYNGAS

BACKGROUND

[0001] 1. Field

[0002] The disclosed embodiments relate to a method and to apparatus for treating a synthesis gas or "syngas". It also relates to a system for treating waste or biomass, which system is equipped with such treatment apparatus.

[0003] 2. Brief Description

[0004] Methods are known that make it possible to obtain a syngas.

[0005] Autothermal gasification is, for example, a well known method whose main mechanism seeks, in oxygen under-stoichiometry and by injecting steam, to decompose carbon chains such as those contained in biomass, forest residues, household and hospital waste, soiled wood, and any other waste having high organic potential, with a view to a obtaining a syngas that is combustible and suitable for use in recycling.

[0006] The definite advantage procured by gasification is that, in the absence of full combustion, the organic fraction decomposes in the form of a combustible gas (fuel gas) whose "lower combustion value" or "net calorific value" (NCV) increases with decreasing presence of carbon dioxide, of water vapor, and of nitrogen, these molecules being inefficient when used in recycling as means to generate electricity, as biofuel, or in organic chemistry.

[0007] In addition, the presence of tar and of solid carbon in the syngas constitutes a major drawback for the elements downstream from the gasification reactor. Such particles can condense easily in the syngas treatment pipes, thereby giving rise to obstruction of said pipes and to risks of fire starting spontaneously on opening the pipes for maintenance purposes. Furthermore, such solid elements can build up on gas turbine blades and in gas engines, thereby lastingly reducing performance thereof and increasing frequency of servicing and maintenance thereof.

[0008] The vast majority of technologies for preparing syngas prior to use in recycling consist in removing the solid particles (tars and solid carbon) as soon as the syngas leaves the autothermal gasification reactor, such removal being by filtration (cyclonic filter, bag filter, electrostatic filter), condensation (water scrubber, oil scrubber), or cracking the solid particles by using catalytic reactions (using pure oxygen and steam) or indeed by high-temperature reforming (using pure oxygen).

[0009] Autothermal gasification suffers from intrinsic temperature limitation which, de facto, limits the NCV of the syngas produced. The constraints imposed by the design of autothermal gasification reactors, the refractory materials of which they are made, and the presence of moving elements (rakes made of refractory steel, sands, metal balls) making it possible to homogenize the load, mean that it is difficult for temperatures higher than 850° C. to be withstood.

[0010] Treatment capacity is also limited by the variability of the incoming matter in terms of composition and grainsize, and by its humidity level and its mineral content, and in particular its heavy metal content.

[0011] Those factors result in gasification methods being performed at temperatures lying in the range 600° C. to 850° C. in order to be economically viable. Therefore, at such temperatures, it is necessary to accept obtaining a syngas with a mediocre NCV because although it admittedly contains carbon monoxide and hydrogen as dominant species, it also contains by-products that cannot be used in recycling, such as carbon dioxide, water vapor, and nitrogen.

[0012] As regards the solid particles in suspension in the syngas, the approach consists in extracting them from the syngas and in recycling them back into the reactor as a thermal energy source. That action, which consists in removing that carbon potential initially available in the organic material to be treated from the gasification method gives rise to a limitation of the carbon efficiency, the direct consequence of which is a limitation in the NCV.

[0013] The risks are also environmental and health ones for the operators. Extracting solid particles in suspension in the syngas generates residual sludge in the syngas treatment system. That sludge then needs to be removed from the site to landfills or to industrial waste incinerators. The operators are thus exposed to carcinogenic products during maintenance of the scrubbers or of the sewage treatment plants.

[0014] The flows of multi-phase waste, such as the mixture with the ashes at the bottom of the gasification reactor, and the residual sludge (tars/solid carbon/water/oil) coming from the treatment line for treating the syngas prior to use in recycling represent a considerable economic cost as regards removing them from the site to landfill or destruction sites.

[0015] Another gasification method is known, namely direct gasification using plasma. That method consists in attacking the organic material directly with plasma so as to convert it into a high-purity, high-temperature syngas.

[0016] The general configuration of such a method is usually as follows: one or more plasma tools deliver one or more plasma flows into a furnace fed with materials to be gasified and/or to be vitrified. The furnace then hosts thermochemical reactions for transforming the materials fed in, under the direct action and/or the indirect action of the plasma flow. The liquid and gas phases that result from the synthesis or from the plasma treatment are then recovered for any subsequent treatment implementing existing techniques.

[0017] The essential components of such installations, except for the plasma tools implemented in the method, comprise apparatus for injecting solid matter in powder form, or for injecting liquid, or indeed for injecting semi-liquid substances (sewage plant sludge, petroleum sludge).

[0018] Directly attacking incoming matter having a high organic content is not economically viable insofar as extracting the humidity fraction contained in the organic material gives rise to electricity consumption which is less pertinent than using thermal energy recycled from the method.

[0019] Furthermore, the use of a single furnace lined with refractory material and that must cope with the liquid, solid, and gas phases gives rise to operating modes that limit the flow rate of incoming matter or the variability of the incoming matter.

[0020] It is the portion of the furnace that has to cope with the liquid mineral that withstands refractory lining corrosion/impregnation for the shortest amount of time. That portion is thus the floor of the furnace, which requires the gasification method to be stopped in order to perform maintenance on said floor.

[0021] The mixture of the plasma and of the materials to be gasified and/or to be vitrified does not include all of the materials, the thermochemical treatment mainly concerning an indirect process (thermal radiation coming form the refractory walls of the furnace that are heated to high temperatures under the action of the plasma). Therefore the energy transfer between the plasma and the materials is not optimized.

[0022] Moreover, manufacturing the furnace requires the use of refractory materials whose erosion is very sensitive to the variations in temperature generated by varying energy needs corresponding to the variable chemical composition of the incoming materials, and by the periodic removal of the plasma tool for the purpose of changing electrodes. In addition, the chemical natures of the gases resulting from the plasma treatment can also limit the life of the refractory linings, in particular when said gases contain chlorine.

SUMMARY

[0023] An object of the disclosed embodiments is thus to propose an indirect gasification stage for indirectly gasifying organic materials using plasma with a view to transforming a gas of medium temperature, seeded with solid particles such as particles of tar and/or of solid carbon, coming from an autothermal pyrolysis or gasification reactor in order to obtain a syngas having high purity, and having reinforced carbon potential, and whose main components are carbon monoxide and hydrogen (dihydrogen).

[0024] To this end, the disclosed embodiments provide a method of treating a synthesis gas or "syngas".

[0025] According to the disclosed embodiments, this method comprises the following steps:

[0026] generating a plasma jet from a non-transferred-arc torch having a main axis, said jet having a propagation axis that is substantially collinear with the main axis of said torch, said plasma torch being mounted on a feed enclosure;

[0027] receiving said syngas at least one inlet port of said feed enclosure, said inlet port being placed downstream from said plasma torch, and feeding said syngas in so that the flow of syngas encounters said plasma jet at least partially so as to mix said syngas and said plasma jet;

[0028] propagating said mixture in an elongate reactor placed downstream from said inlet port for the purpose of converting said syngas into an outlet gas, said reactor being in communication in its upstream portion with said feed enclosure and having a longitudinal axis that is substantially collinear with the propagation axis of said plasma jet; and

[0029] extracting the outlet gas via an outlet port.

[0030] The expression "propagation axis that is substantially collinear with the main axis of the torch" is used to mean that the propagation axis of the plasma jet is either collinear with or coincides with the axis of the torch, or else that the volume of space occupied on average over time by the plasma jet has its axis coinciding with the main axis of the plasma torch. Under the effect of the forces exerted by the flow of syngas fed into the feed enclosure, the end of the plasma jet can be placed on either side of the main axis of the torch. However, the plasma jet occupies on average over time a position that coincides with the main axis of the torch.

[0031] The expression "longitudinal axis of the reactor that is substantially collinear with the propagation axis" is used to mean that the longitudinal axis is either collinear with or coincides with the propagation axis, or else that said longitudinal axis is substantially aligned on said propagation axis.

[0032] The expression "placed downstream from" is used to mean placed beyond, in the propagation direction of the plasma jet.

[0033] Whereas it is possible to separate the solid, liquid, and gas flows in prior art gasification apparatus, enabling the organic materials contained in the biomass or in the waste to be managed simply and basically, under controlled economic and operational conditions, the method of treatment of the disclosed embodiments offers the advantage of being highly flexible and of adapting to accommodate all of the situations encountered in implementing a gasification method, with a single aim: to reinforce the working potential of the carbon contained in the syngas to be treated, and to make the composition of said syngas tend towards two majority elements only, namely carbon monoxide (CO) and dihydrogen (H_2).

[0034] It is not therefore necessary to know the initial composition of the syngas to be treated.

[0035] It is possible to apply an instantaneous adjustment in the quality of the outlet gas by adjusting the temperature of the plasma jet coming from the plasma torch. Adjusting the operational parameters of the torch is technically feasible within a time shorter than one second.

[0036] In addition, bringing the syngas up to temperature does not give rise to any reduction in carbon monoxide through oxidation with air. Even if the plasma jet were formed with air as the plasma-generating gas, the plasma jet is not a flame and does not require any supply of combustion air in order to generate heat. The plasma jet, with its 5000° K on average is a flow of ionized gaseous matter, in extinction, electrically neutral, and seeded with species such as electrons, ions, atoms, and radicals having high chemical reactivity. The radicals preferably go to re-associate with the species released by cracking of the non-advantageous molecules of the syngas to be treated brought up to temperature. Thus, the triatomic molecules (CO_2, H_2O) and the molecules having even more atoms (CH_4, C_nH_m) that have low atomic bonding potential break apart and tend to produce carbon monoxide (CO) and additional dihydrogen (H_2).

[0037] In various particular implementations of this method of treating a syngas, each having its own advantages and being susceptible of numerous technically feasible combinations:

[0038] the syngas is fed in in a direction that is distinct from the propagation axis so as to establish a turbulent mixing zone between the plasma jet and the syngas;

[0039] at least one fluid is fed into the feed enclosure and/or into the reactor in order to adjust the composition of the syngas to be treated;

[0040] said at least one fluid can be fed in by at least one injector, at least one injection orifice for injecting a protective fluid, the plasma torch, or a combination of said elements;

[0041] advantageously, this fluid may be chosen from the group comprising water, carbon dioxide, and a combination of these elements;

[0042] the speed of the syngas/plasma jet mixture is reduced at the inside wall of the feed enclosure and/or of the reactor;

[0043] the reduction in the speed of the mixture can be obtained by feeding in a protective fluid tangentially to the wall of the feed enclosure and/or of the reactor, said fluid being at ambient temperature; this fluid also makes it possible to protect the refractory materials with which the feed enclosure and the reactor are advantageously equipped;

[0044] this reduction in speed can also be obtained by increasing the through cross-section of the plasma jet with the presence of a flared portion in the feed enclosure in order to optimize injection of said at least one fluid for adjusting the composition of the syngas to be treated;

[0045] the outlet gas is accelerated in the downstream portion of the reactor prior to it being extracted via the outlet port;

[0046] the outlet gas is quenched so as to set said outlet gas;

[0047] the component species of the outlet gas are thus set, thereby preventing any recombination of said species, which would give rise to a reduction in the majority species H_2 and CO;

[0048] a protective fluid at ambient temperature is fed in tangentially to the walls of the feed enclosure and/or of the reactor, over at least a portion of said walls;

[0049] this protective fluid makes it possible to protect the walls of the feed enclosure and/or of the reactor from the plasma jet; and

[0050] the temperature of the outlet gas is measured and the temperature of the plasma jet is adjusted so as to control the conversion of said syngas into outlet gas.

[0051] The disclosed embodiments also provide apparatus for implementing the method as described above. According to the disclosed embodiments, said apparatus comprises:

[0052] a feed enclosure to which a reactor is connected, the feed enclosure and the reactor each having an internal volume defined by walls covered at least partially with refractory elements, said enclosure and said reactor being in fluid communication;

[0053] the feed enclosure includes a non-transferred-arc plasma torch having a main axis, said torch serving to generate a plasma jet having a propagation axis that is substantially collinear with the main axis of said torch;

[0054] the feed enclosure is provided with at least one inlet port (**7**) placed downstream from the plasma torch (**3**) for the purpose of feeding in a syngas in a manner such that said syngas is mixed with the plasma jet; and

[0055] the reactor has a substantially cylindrical elongate shape, the longitudinal axis of said reactor being substantially collinear with the propagation axis of the plasma jet, said reactor having an outlet port for the outlet gas in its downstream portion.

[0056] This system can be said to have an "in-line" configuration, i.e. the plasma torch, then the injection apparatus, then the reactor, as opposed to the conventional configuration in which the reactor is coupled simultaneously (in "parallel") to the torch and to the injection apparatus for injecting the material to be treated.

[0057] This in-line configuration offers numerous advantages, in particular it is very simple to operate, it has a suction effect whereby the syngas is sucked in by the plasma jet, and it also offers entrainment of the syngas/plasma jet mixture along a straight line (propagation axis) thereby minimizing any interactions between the overheated mixture and the walls of the feed enclosure and of the reactor.

[0058] The intimate mixture of the syngas and of the plasma jet also makes it possible to transfer energy directly between the plasma jet and the syngas, thereby making it possible not only to consume less energy but also to achieve syngas/plasma jet mixture temperatures that are higher than with prior art apparatus.

[0059] In various particular implementations of this method of treating a syngas, each having its own advantages and being susceptible of numerous technically feasible combinations:

[0060] the apparatus further comprises a fluid injector for adjusting the composition of said syngas to be treated, said at least one injector serving to feed said fluid in substantially in the direction in which the syngas/plasma jet mixture flows;

[0061] with said injectors being placed in the downstream portion of said feed enclosure and/or in the upstream portion of said reactor, said downstream portion includes a flared segment that flares in the same direction as the direction in which said propagation axis extends so as to reduce the speed of said syngas/plasma jet mixture, and so as to optimize injection of said fluid;

[0062] the feed enclosure and the reactor are provided with injection orifices for injecting a protective fluid, which orifices are connected to an injection circuit for injecting said fluid;

[0063] with the plasma jet having a diameter d, the inlet port has a feed orifice for feeding in said syngas whose diameter D is such that D/d is greater than or equal to 10;

[0064] this ratio between the diameter of the feed orifice and the diameter of the plasma jet makes it possible to avoid head loss at the interface between the inlet port and the internal volume of the feed enclosure. It is thus possible to avoid putting the syngas under pressure while it is being fed in, which could result in less good coupling between the syngas and the plasma jet;

[0065] merely by way of illustration, with the diameter d of the plasma jet being 50 mm, the diameter D of the feed orifice is 800 mm; and

[0066] the outlet port is connected to at least one setting means for setting the outlet gas.

[0067] For example, the setting means comprise at least one heat exchanger that makes it possible to quench the outlet gas.

[0068] The disclosed embodiments also provide a system for treating waste or biomass, which system comprises a first treatment stage for treating waste or biomass, which first stage receives said waste or said biomass and generates a syngas, and a second treatment stage coupled to said first stage for the purpose of receiving said syngas.

[0069] According to the disclosed embodiments, the second stage is constituted by apparatus for treating the syngas as described above.

[0070] This system makes it possible to produce an outlet gas that is a purified syngas containing a majority of the species H_2 and CO. This syngas purified by non-transferred-arc plasma torch and having a higher calorific value than it had prior to treatment, has a value in use that predestines it advantageously for use in electricity generation, in producing biofuel, or in organic chemistry, e.g. for producing synthetic polymer.

[0071] The disclosed embodiments therefore also provide a system for generating electrical energy from waste or biomass, said system comprising at last one gas turbine or at least one gas engine. According to the disclosed embodiments, said system for generating electrical energy is equipped with a system for treating waste or biomass as described above. Said at least one gas turbine, or said at least one gas engine, is actuated by said outlet gas generated by said system for treating waste or biomass.

[0072] The disclosed embodiments also provide a system for producing a synthetic fuel or "synfuel" from waste or from biomass, said system comprising at least one catalytic reactor. According to the disclosed embodiments, said system is equipped with a system for treating waste or biomass as described above.

[0073] Preferably, since said catalytic reactor generates a residual gaseous product, said system further comprises a looping circuit connected firstly to said catalytic reactor for the purpose of recovering said residual gaseous product, and secondly to at least one of the elements chosen from the group comprising at least one injector, at least one injection orifice, said plasma torch, and a combination of these elements for the purpose of feeding said gaseous product into said treatment apparatus. Said looping circuit includes a compressor for compressing said residual gaseous product prior to it being fed into said apparatus.

[0074] This catalytic reactor is preferably a reactor making it possible for the "Fischer-Tropsch" reaction to take place, i.e. hydrocarbons to be produced by causing a mixture comprising at least carbon monoxide and hydrogen to react in the presence of a catalyst. This method is a well-known industrial method that is not described herein.

[0075] The catalysts used can be of various types and they generally comprise at least one metal chosen from the group comprising iron, cobalt, ruthenium, and vanadium.

[0076] The metal is typically dispersed over a medium that can comprise a porous mineral material such as an oxide chosen from the group comprising alumina, silica, titanium oxide, zirconium, rare earths, and combinations of these elements.

[0077] The catalyst can, in known manner, further comprise one or more activation agents chosen from at least one of the groups I to VII of the periodic table.

[0078] Merely by way of illustration, the catalytic reactor can be a reactor of the bubble column type.

[0079] Since the exhaust gas or the residual gaseous product from the catalysis is fed back in or recycled into the treatment apparatus via the looping circuit, an electricity generation system or a synfuel production system is thus obtained that emits a low level of pollution.

BRIEF DESCRIPTION OF THE DRAWINGS

[0080] The disclosed embodiments are described in more detail below with reference to the accompanying drawings, in which:

[0081] FIG. **1** is a perspective view of apparatus for treating a syngas in a particular embodiment of the disclosed embodiments;

[0082] FIG. **2** is a fragmentary section view of the feed enclosure of the apparatus of FIG. **1**; and

[0083] FIG. **3** is a diagram showing a system for generating electrical energy from waste or biomass, which system incorporates the treatment apparatus of FIG. **1**.

[0084] FIGS. **1** and **2** show apparatus for treating a syngas in a preferred embodiment of the disclosed embodiments. This apparatus, which forms an in-line system, includes a feed enclosure **1** to which a reactor **2** is connected.

DETAILED DESCRIPTION

[0085] The feed enclosure **1** and the reactor **2** each have an internal volume defined by walls, which walls are covered, on the inside, with refractory materials that withstand high temperatures, e.g. based on chromium/corundum. These refractory materials make it possible, in particular, to reduce heat losses.

[0086] The feed enclosure **1** and the reactor **2** which, in this example, are made of metal, are cooled by an external pressurized fluid circuit, the cooling fluid being, for example, demineralized water. However, the apparatus is designed not to have any cold spots that might constitute zones for condensation of the particles present in the syngas.

[0087] The feed enclosure **1** includes a non-transferred-arc or "blown arc" plasma torch **3**. This torch **3** is designed to generate a plasma jet **4** having a propagation axis **6** that is substantially collinear with the main axis of the torch **3**.

[0088] The use of such a torch **3** makes it possible not only to obtain a plasma jet that has a very high temperature, typically lying in the range 2000° C. to 5000° C. as a function of the power of the torch implemented, but also to procure full independence between the internal volume of the feed enclosure **1** and the plasma torch **3**. The feed enclosure **1** therefore has a cooled isolation valve **6** making it possible to isolate the torch **3** from the feed enclosure **1**. It is then possible to work on the torch **3** without exposing the apparatus as a whole to air.

[0089] The apparatus advantageously includes automatic permutation means for permuting a first transferred-arc torch with a second transferred-arc torch in order to replace a torch that requires maintenance or in order to increase the power of the torch. Merely by way of illustration, these automatic permutation means can be actuated hydraulically.

[0090] The feed enclosure **1** is preferably provided with orifices (not shown) through which a protective fluid can be injected. These orifices are connected to an injection circuit for injecting said protective fluid. This circuit can include a compressor for injecting the protective fluid in pressurized form.

[0091] The injection orifices are directed so that the fluid is injected tangentially to the inside wall of the feed enclosure **1** so as to surround the plasma jet **4** delivered by the torch **3** and so as to prevent the jet from licking said inside wall directly, which would be detrimental to the structural integrity of the feed enclosure. The protective fluid can be a gas at ambient temperature, the gas preferably being the syngas. It can also be constituted by a liquid such as water or oil. When it is oil, it can be constituted by biomass oil, engine oil, or frying oil.

[0092] The feed enclosure **1** is also provided with an inlet port **7** placed downstream from the plasma torch **3** for the purpose of feeding in the syngas to be treated in the vicinity of the plasma jet **4**. The inlet port **7**, which, in this example, is in the form of a bend, is directed in a manner such as to feed in the syngas in a direction that is distinct from the propagation axis **5** of the plasma jet **4**, so as to establish a turbulent mixture zone between the plasma jet and the syngas. This turbulent mixture zone makes it possible to procure intimate mixing between the syngas to be treated and the plasma jet **4**. The syngas is, in this example, fed in perpendicularly to the propagation axis of the plasma jet.

[0093] More generally, the angle formed between the main axis of the bend and the propagation axis **5** of the plasma jet results from computations and experimentations taking account of the parameters of the plasma jet **4** generated by the non-transferred-arc torch **3** and of the flows to be treated (syngas and components for adjusting the composition of said syngas). Merely by way of illustration, this angle can lie approximately in the range 90° to 135°.

[0094] The propagation axis **5** of the plasma jet is directed so as to direct the syngas/plasma jet mixture towards the reactor **2** in which the syngas hosts reactions leading to it being transformed into the outlet gas.

[0095] In addition, as a function of the initial distribution of the main components (C, H, O) in the organic materials present in the waste or biomass leading to the syngas to be treated, it is possible that the removal of tar, of water, and of carbon dioxide by treating the syngas in the apparatus of the disclosed embodiments might not generate sufficient carbon monoxide (CO) or hydrogen in the outlet gas for significant use in energy generation.

[0096] Injectors **8** are therefore placed on the feed enclosure **1** for inserting one or more fluids with a view to adjusting the composition of the syngas to be treated. For example, the injectors can be injection nozzles for injecting a gas such as CO_2, or nebulizers when a liquid, such as water, is injected. A combination of these elements can also be implemented.

[0097] Said injectors **8** are preferably placed in a manner such as to feed in the materials substantially in the direction of the flow of the syngas/plasma jet mixture.

[0098] These fluids are intrinsically available on site, because they are recycled from the downstream stages of the treatment method of the disclosed embodiments.

[0099] In order to optimize injection of these fluids, the feed enclosure **1** has a flared segment **9** in its downstream portion, the flared segment being flared in the same direction as the direction in which the plasma jet propagates along its propagation axis **5**, thereby making it possible to reduce the speed of the plasma jet **4**. In this example, this flared segment **9** is a nozzle of the blast pipe type.

[0100] The reactor **2** has a substantially cylindrical elongate shape and, in its downstream portion, is provided with an outlet port **10** for the outlet gas. The cylindrical geometrical shape of the reactor **2** is designed so as advantageously to limit the speed of the syngas/plasma jet mixture at the wall of the reactor **2**, this speed being induced by the speed of the plasma jet at the outlet of the torch **3** (typically 400 meters per second (m/s). Generating a protective film over the wall of the reactor and/or of the feed enclosure by feeding in a protective fluid also makes it possible to reduce the speed of the syngas/plasma jet mixture at said walls. It is known that the refractory materials protecting the inside wall of the reactor **2** and of the feed enclosure have low resistance to friction (of about 10 m/s).

[0101] The longitudinal axis of said reactor **2** is substantially collinear with the propagation axis **5** of the plasma jet so as to limit the contact between the plasma jet and the walls of the reactor **2**.

[0102] Said reactor **2** constitutes a thermal or thermochemical transformation zone for thermally or thermochemically transforming the syngas to be treated with a view to it being converted into outlet gas. This zone results from the intimate mixing of the syngas to be treated and of the plasma jet that takes place in the feed enclosure **1**. The length of said reactor **2**, or furnace, is determined in order to optimize the residence time of the materials to be synthesized or to be treated, which residence time is necessary for accomplishing the thermochemical reactions.

[0103] The reactor **2** is also provided with injection orifices for injecting a protective fluid, which orifices are connected to a circuit for injecting said fluid.

[0104] In its downstream portion, the reactor **2** preferably has a constriction **11** connected to the outlet port **10**. This constriction makes it possible to accelerate the outlet gas prior to it being extracted via the outlet port **10**.

[0105] This acceleration makes it possible to obtain a speed that is sufficient to send the outlet gas into a heat exchanger (not shown) connected to the outlet port **10**. This heat exchanger makes it possible to quench the outlet gas and to set the component species of the outlet gas.

[0106] Between the outlet port **10** and the constriction **11**, a duct **12** is placed that is lined with refractory materials.

[0107] The apparatus is provided with at least one sensor (not shown) for measuring the temperature of the outlet gas in a manner such as to adjust the quality of the outlet gas by adjusting the temperature of the plasma jet **4** coming form the plasma torch **3**. The adjustment of the operating parameters of the plasma torch **3** is technically feasible in a time shorter than one second. The sensor can be an optical pyrometer or a temperature probe mounted on the wall of the duct **12**.

[0108] The feed enclosure **1** and the reactor **2** can have coupling pieces respectively at the inlet port **7** and at the outlet port **10** making it possible to mount said apparatus onto a more complex system such as a system for treating waste or biomass, or for generating electrical energy from waste or from biomass (FIG. **3**). These coupling pieces have shapes chosen from the group comprising a rectangular shape and a cylindrical shape.

[0109] A way of using the outlet gas from the syngas treatment method of the disclosed embodiments is described below.

[0110] FIG. **3** is a diagram showing a system for generating electricity from waste or from biomass in a particular embodiment of the disclosed embodiments.

[0111] This system includes a first stage **13** for treating waste or biomass. The first stage receives waste or biomass at its inlet and generates syngas at its outlet. This stage can, in a known manner, be an autothermal gasification reactor or a single-stage gasification reactor using thermal plasma. The syngas is sent to treatment apparatus **14** for treating the syngas as described above, which apparatus makes it possible to produce an outlet gas. At the outlet of the apparatus, the gas has a temperature lying in the range 1150° C. to 1300° C.

[0112] The outlet gas is sent to a first heat exchanger **15** for the purpose of setting the gas and of cooling it to a temperature lying in the range 400° C. to 600° C. The outlet gas treated in this way is then sent to a second heat exchanger **16**, at the outlet of which its temperature is in the vicinity of in the range 100° C. to 200° C.

[0113] The outlet gas then enters a dust collection unit **17** making it possible to collect the particles before the gas is sent into a bag filter **18**. Finally a gas scrubber **19** that makes it possible to solubilize a gaseous pollutant in a liquid is implemented for removing, in particular, any traces of sulfur dioxide or of chlorine. A compressor **20** makes it possible to put the outlet gas treated in this way under extra pressure on a gas turbine **21**. The outlet gas actuates the gas turbine **21** which is connected to an alternator **22** which transforms the mechanical energy into electrical energy.

[0114] The gas turbine **21** can be replaced merely by a gas engine if the flow rate of the outlet gas is not sufficiently high. Preferably, since the gas turbine (or the gas engine) generates an exhaust gas, the system includes a looping circuit **23** connected firstly to said gas turbine (or to said gas engine) for the purpose of recovering the exhaust gas, and secondly to at least one of the elements chosen from the group comprising at least one injector, at least one injection orifice, the plasma torch, and a combination of these elements, for the purpose of feeding the exhaust gas into the treatment apparatus **14**. The looping circuit **23** also includes a compressor (not shown) for compressing the exhaust gas before it is fed into the apparatus. The exhaust gas is typically carbon dioxide.

1. A method of treating a synthesis gas or "syngas", said method being characterized in that it comprises the following steps:

generating a plasma jet (**4**) from a non-transferred-arc torch (**3**) having a main axis, said jet having a propagation axis (**5**) that is substantially collinear with the main axis of said torch, said plasma torch (**3**) being mounted on a feed enclosure (**1**);

receiving said syngas at at least one inlet port (**7**) of said feed enclosure (**1**), said inlet port (**7**) being placed downstream from said plasma torch (**3**), and feeding said syngas in so that the flow of syngas encounters said plasma jet (**4**) at least partially so as to mix said syngas and said plasma jet;

propagating said mixture in an elongate reactor (**2**) placed downstream from said inlet port (**7**) for the purpose of converting said syngas into an outlet gas, said reactor (**2**) being in communication in its upstream portion with said feed enclosure (**1**) and having a longitudinal axis that is substantially collinear with the propagation axis (**5**) of said plasma jet; and

extracting the outlet gas via an outlet port (**10**).

2. A method according to claim **1**, characterized in that said syngas is fed in in a direction that is distinct from said propagation axis (**5**) so as to establish a turbulent mixing zone between the plasma jet (**4**) and said syngas.

3. A method according to claim **1**, characterized in that at least one fluid is fed into the feed enclosure (**1**) and/or into the reactor (**2**) in order to adjust the composition of the syngas to be treated.

4. A method according to claim **3**, characterized in that said fluid is chosen from the group comprising water, carbon dioxide, and a combination of these elements.

5. A method according to claim **1**, characterized in that the speed of the syngas/plasma jet mixture is reduced at the inside wall of said feed enclosure (**1**) and/or of said reactor (**2**).

6. A method according to claim **1**, characterized in that said outlet gas is accelerated in the downstream portion of the reactor (**2**) prior to it being extracted via said outlet port (**10**).

7. A method according to claim **1**, characterized in that said outlet gas is quenched so as to set said outlet gas.

8. A method according to claim **1**, characterized in that the temperature of said outlet gas is measured and the temperature of said plasma jet (**4**) is adjusted so as to control the conversion of said syngas into outlet gas.

9. Apparatus for implementing the method of processing a syngas according to claim **1**, said apparatus being characterized in that it comprises:

a feed enclosure (**1**) to which a reactor (**2**) is connected, said feed enclosure (**1**) and said reactor (**2**) each having an internal volume defined by walls covered at least partially with refractory elements, said enclosure (**1**) and said reactor (**2**) being in fluid communication;

said feed enclosure (**1**) including a non-transferred-arc plasma torch (**3**) having a main axis, said torch serving to generate a plasma jet (**4**) having a propagation axis (**5**) that is substantially collinear with the main axis of said torch;

said feed enclosure (**1**) being provided with at least one inlet port (**7**) placed downstream from said plasma torch (**3**) for the purpose of feeding in a syngas in a manner such that said syngas is mixed with said plasma jet (**4**); and

said reactor (**2**) having a substantially cylindrical elongate shape, the longitudinal axis of said reactor (**2**) being substantially collinear with the propagation axis of said plasma jet (**4**), said reactor (**2**) having an outlet port (**10**) for said outlet gas in its downstream portion.

10. (canceled)

11. Apparatus according to claim **9**, characterized in that it further comprises a fluid injector (**8**) for adjusting the composition of said syngas to be treated, said at least one injector (**8**) serving to feed said fluid in substantially in the direction in which the syngas/plasma jet mixture flows.

12. Apparatus according to claim **9**, characterized in that with said injectors (**8**) being placed in the downstream portion of said feed enclosure (**1**) and/or in the upstream portion of said reactor (**2**), said downstream portion includes a flared segment (**9**) that flares in the same direction as the direction in which said propagation axis (**5**) extends so as to reduce the speed of said syngas/plasma jet mixture, and so as to optimize injection of said fluid.

13. Apparatus according to claim **9**, characterized in that said feed enclosure (**1**) and said reactor (**2**) are provided with injection orifices for injecting a protective fluid, which orifices are connected to an injection circuit for injecting said fluid.

14. Apparatus according to claim **9**, characterized in that with said plasma jet (**4**) having a diameter d, said inlet port (**7**) has a feed orifice for feeding in said syngas whose diameter D is such that D/d is greater than or equal to 10.

15. Apparatus according to claim **9**, characterized in that said outlet port (**10**) is connected to at least one setting means (**15**, **16**) for setting said outlet gas.

16. A system for treating waste or biomass, which system comprises a first treatment stage for treating waste or biomass, which first stage receives said waste or said biomass and generates a syngas, and a second treatment stage coupled to said first stage for the purpose of receiving said syngas, said system being characterized in that said second stage is constituted by apparatus for treating said syngas according to claim **9**.

17. A system for generating electrical energy from waste or biomass, said system comprising at last one gas turbine (**21**) or at least one gas engine, said system for generating electrical energy being characterized in that it is equipped with a system for treating waste or biomass according to claim **16**, and in that said at least one gas turbine (**21**), or said at least one gas engine, is actuated by said outlet gas generated by said system for treating waste or biomass.

18. A system for generating electrical energy according to claim **17**, characterized in that, since said at least one gas turbine (**21**) or said at least one gas engine generates an exhaust gas, said system further comprises a looping circuit (**23**) connected firstly to said at least one gas turbine (**21**) or to said at least one gas engine for the purpose of recovering said exhaust gas, and secondly to at least one of the elements chosen from the group comprising at least one injector (**8**), at least one injection orifice, said plasma torch (**3**), and a combination of these elements for the purpose of feeding said exhaust gas into said treatment apparatus, said looping circuit (**23**) including a compressor for compressing said exhaust gas prior to it being fed into said apparatus.

19. A system for producing a synthetic fuel or "synfuel" from waste or from biomass, said system comprising at least one catalytic reactor, said system being characterized in that it is equipped with a system for treating waste or biomass according to claim **16**.

20. A system for producing a synthetic polymer from waste or from biomass, said system comprising at least one catalytic reactor, said system being characterized in that it is equipped with a system for treating waste or biomass according to claim **16**.

21. A system according to claim **19**, characterized in that since said catalytic reactor generates a residual gaseous product, said system further comprises a looping circuit connected firstly to said catalytic reactor for the purpose of recovering said residual gaseous product, and secondly to at least one of the elements chosen from the group comprising at least one injector, at least one injection orifice, said plasma torch, and a combination of these elements for the purpose of feeding said gaseous product into said treatment apparatus, said looping circuit including a compressor for compressing said residual gaseous product prior to it being fed into said apparatus.

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