

SYNTHESIS-GAS-REACTOR WITH PRE-HEATING FOR SEPARATED WATER FEEDING AND PROCESS FOR IT

Field of the Invention

- 5 The invention is generally in the field of reactors that perform chemical conversions of fed organic materials to synthesis-gas based on heating the fed organic material, thus adding energy from outside to the performed chemical-reaction, to a temperature that the fed material reacts with water to generate synthesis-gas, which is a combustible gas-mixture, usually with relatively low energy-content, mainly consisting of carbon-monoxide, methane, some smaller hydro-
10 carbon molecules, hydrogen, and residues of the reaction and the feedstock.

Those reactors are generally referred to as: shift-gas-reactors, pyrolysis-reactors, hydrolysis-reactors, bio-gas-reactors, sump-gas-reactors, and various other names.

- Those types of reactors are widely in use in many fields from treating waste, to gasify coal. The
15 invention here is a type of such synthesis-gas reactors with additional features for dividing the reaction into two main steps to enable more control of the reaction, to the end to save energy and improve and control the energy-content and homogeneity of the generated synthesis-gas.

Background of the Invention

- 20 Synthesis-gas reactors are known under many different names, which also change and changed over the many years, in which such reactors are used, and also with the purpose of such reactors. What they have all in common is firstly: these reactors need added thermal energy which is required to break up at least a large part of the molecules of the feedstock, thus enabling the desired chemical-reaction,
25 and secondly: the kind of reductive chemical-reaction of the carbon-molecules of the broken-up molecules of the feedstock with the hydrogen, which is usually provided for the chemical-reaction in form of water, which is either at least partly in the feedstock or at least partly added to the feedstock.

- The generated synthesis-gas of such a chemical-reaction contains compounds, which can be used
30 as fuel, as they are combustible.

Depending on the feedstock, the generated synthesis-gas has a relatively low energy-content, compared to other fuels and or combustible compounds.

Depending on the feedstock the generated synthesis-gas can vary in its composition, thus a

fluctuation of the energy-content over time can occur.

In case of a relatively homogenous composition feedstock – for example rice-straw – this fluctuation or change of composition of the synthesis-gas is less, and thus the energy content more even over time, than in a less homogenous composition feedstock – for example municipal-
5 waste – where it is difficult to keep the generated synthesis-gas homogeneous.

The chemical reaction of the more complex carbon-hydrogen-compounds of the feedstock to form smaller, less complex molecules, like carbon-monoxide and methane, requires hydrogen as reducing compound – what could be seen as analogue to the need of oxygen as a oxidizing
10 compound in a combustion.

These necessary hydrogen-molecules are usually provided in the chemical reaction in such synthesis-gas-reactors in form of water. This water is either already in the feedstock or is added to the chemical-reaction.

The chemical-reaction in the synthesis-gas-reactor requires thermal-energy that is added to the
15 chemical-reaction, as it is not provided by the chemical-reaction itself – as this would be the case in a combustion-reaction. This thermal energy is added from outside by heating elements.

Ways to add this thermal energy are: heating with electric-heaters, oxygen jets, burners, ionization and/or the use of one or several plasma torches.

20 The feedstock of a synthesis-gas-reactor can be from case to case completely different, depending on many reasons, one would just be: for which purpose the synthesis-gas-reactor is used. Thus, also the water content of the feedstock can be completely different from case to case. In case of dry wood as feedstock, the water content would be around 30%, while with wood that had not been dried, the water content would be around 70%.

25 Usually the largest part or at least a significant part of the energy, which is added to the synthesis-gas-reactor from outside, is used in the synthesis-gas reactor to first evaporate the water in the feedstock, or the water that had to be added, thus to change water from its liquid form to its gaseous form, before it can take part in the chemical reactions in the synthesis-gas-
30 reactor.

When the feedstock enters the synthesis-gas-reactor, then the feedstock is at a temperature level, which is too low to start the desired chemical-reaction. When the feedstock is heated, then the mass of the feedstock receives thermal energy and the temperature of the feedstock inside the synthesis-gas-reactor rises.

When the temperature of the feedstock reaches the temperature, which is needed to evaporate water, usually around 100°C (212°F), then the added thermal energy is first consumed for the evaporation of the water-content of the feedstock, until almost all of the water is evaporated, before the temperature of the feedstock continues to rise further, beyond the temperature of
5 around 100°C (212°F).

The evaporation of the water-content of the feedstock needs a specific amount of energy per kilogram of water, referred to as evaporation-enthalpy, as the heating of all other compounds also needs a specific amount of energy per kilogram of that compound. The specific amount of thermal energy that is required to evaporate water is much higher than the specific amount of
10 thermal energy that is required to heat other materials.

As a direct consequence of the fact that water needs significantly more energy to be evaporated, than other compounds of the feedstock need to be heated to the designed temperature, also the time that is needed in a synthesis-gas-reactor to evaporate the water content of the feedstock or
15 the added water, is significantly more, than time needed to heat other compounds of the feedstock in the synthesis-gas-reactor. Thus, the size of such a synthesis-gas-reactor significantly depends on the time it takes inside the synthesis-gas-reactor to evaporate the water content or the added water before a higher temperature of the feedstock can be reached.

20 In case that the water content of the feedstock is changing over time, as it is for example the case with house-hold-waste or waste from wood-processing, an additional problem arises: the composition of the generated synthesis-gas changes and with it its energy-content. In turn also the time for a complete chemical-reaction in the synthesis-gas-reactor is changing and thus not only the quality of the synthesis-gas or its composition changes, but also the amount of the
25 generated synthesis-gas over time varies.

Used publications:

1. Biofuel's Engineering Process Technology, Marco Aurelio Dos Santos Bernardes, Luxembourg Institute of Science and Technology, Luxembourg.
- 30 2. Lope Tabil, Phani Adapa and Mahdi Kashaninejad, Biomass Feedstock Pre-Processing – Part 1: Pre-Treatment.

Summary of the Invention

By adding as an additional first process-step a preheating step, before the otherwise unchanged synthesis-gas-reactor, and by separating and extracting at this step the steam and other vapour from the feedstock, two parallel partial process-steps are set-up. The main parallel partial process
5 step – containing the remains of the feedstock, after a significant amount of steam and other vapours have been extracted in the additional preheating step – enters the otherwise unchanged synthesis-gas-reactor.

The separated and extracted steam and vapour is sucked out of the preheated feedstock, before the remaining parts of the preheated feedstock enter the synthesis-gas-reactor, thus directly
10 where the preheating step has reached or passed the temperature required for the evaporation of the water content of the feedstock. The sucked-out steam and vapour is fed as steam and vapour, with a temperature above the evaporation-temperature, into a holding tank, parallel to the synthesis-gas-reactor.

From this holding-tank the sucked-out steam and vapour is then fed still as steam and vapour, at
15 a temperature above the evaporation-temperature with a pressure above the ambient pressure inside the synthesis-gas-reactor and a heat-exchanger for a final heat boost into the synthesis-gas-reactor. The said heat exchanger delivers the heat for the steam and vapour for additional raise of its temperature to a very high value. The heating energy can be sourced from a heating element or by recovering heat from hot gases that come out at the end of the process and needs to
20 be cooled down.

This feeding of the hot steam and vapour into the synthesis-gas-reactor is done in a controlled way by a compressor or pump.

This separating of the synthesis-gas-generation into two partial process-steps allows controlling
25 the ratio between on one side the partially dried feedstock that entered the synthesis-gas-reactor after the steam and vapour had been separated and the water in form of the separated and extracted steam and vapour from the holding tank.

As a result, the chemical reaction between the organic compounds in the feedstock and the required water can be kept optimal concerning the ratio of the compounds containing the carbon-
30 compounds and the compounds containing the necessary hydrogen. In addition, the generated synthesis-gas is more homogeneous, even in case of an inhomogeneous feedstock.

Because the separated steam and vapour need to be added to the synthesis-gas-reactor from the separate holding tank and heat exchanger for steam and vapour, some pressure is required to

facilitate a controlled flow or injection of steam and vapour into the synthesis-gas-reactor. This flow or injection in turn allows to deliver the steam and vapour at more than one specific place inside the synthesis-gas-reactor, thus improve the mixture between steam and vapour on one side and the remaining feedstock on the other side. Even additional fluid mechanical effects can be
5 reached with the injection of the steam and vapour.

Further this separation into two partial process-steps – the evaporation or pre-heating step and the reaction inside the synthesis-gas-reactor – allows using a much lower temperature-level for the thermal-energy required for the preheating.

10 Additionally, the synthesis-gas-reactor does not have to perform the necessary heating and converting liquid water into steam, which significantly shortens the time required for the process of converting organic compounds into synthesis-gas and thus allows either increasing the capacity of feedstock per time, or keeping the reactor smaller, without changing the output-quantity of synthesis-gas.

15 As the preheating-step with the task to reach the evaporation-temperature for water operates at a much lower temperature-level, than the chemical reaction to convert organic compounds into synthesis-gas, the preheating step for evaporating water can be realised with simpler means and thus with lower costs, than the synthesis-gas-reactor, where much higher temperatures are required.

20 While the chemical reaction itself in such synthesis-gas-reactors is well known and explored and documented in literally thousands of publications, the other aspects, like mixing the water-molecules, respective hydrogen-containing molecules, with the carbon-containing molecules, or the kinetics of those compounds, and the distribution of thermal energy over time and inside the
25 three-dimensional space of the reactor, receive less attention. However these aspects are also important and decisive for good efficiencies.

The invention here shows a way how to use the separated steam and vapour by means of aimed injections at certain specific locations within the synthesis-gas-reactor to induce a stable vortex,
30 increase the mixing of the compounds in the synthesis-gas-reactor and thus increase the efficiency of the chemical reaction, respectively decrease the quantity of compounds that did not completely react thus increase the yield of combustible synthesis-gas, decrease the time required for the different molecules to react, and thus increase overall yield of combustible gases, efficiency, and controllability of such synthesis-gas-reactors.

In accordance with the scope of the present invention, the invention pertains to a reactor system for the generation of a combustible gas-mixture of carbon-monoxide, methane, carbon-dioxide, hydrogen, water, and other compounds from a provided feedstock of compounds containing

5 carbon and water, said reactor system comprising:

a closed reactor;

means of feeding said feedstock through at least one designated opening into said closed reactor;

heating means for heating said compounds inside said closed reactor from outside said closed reactor;

10 at least one suction means;

at least one holding tank;

at least one other means for receiving or taking and injecting and additional heating of generated steam and other generated vapours from said holding tank,

wherein said heating means is configured for heating said feedstock in at least one preheating

15 step that precedes opening said closed reactor for feeding said feedstock to a temperature that evaporates water contained in said feedstock,

wherein said heating of said compounds inside said closed reactor from outside is made to a temperature that starts a reaction and generates said gas-mixture,

said at least one suction means is configured to suck generated steam and other generated

20 vapours from said feedstock by said preheating step in at least one suction step,

wherein the sucked said generated steam and other generated vapours are forwarded to and stored in said at least one other means for receiving or taking and injecting and additional heating of a stored said generated steam and other generated vapours from said holding-tank into said closed reactor,

25 wherein said at least one other means for receiving or taking and injecting and additional heating of said generated steam and other generated vapours from said holding tank are put up and operated additionally and parallel to said closed reactor.

Brief Description of the Drawings

30 **Fig. 1** is a schematic presentation of the complete system in a most simplified form.

Detailed Description of the Drawings

Fig. 1 is a schematic presentation of the complete system in a most simplified form.

At the top of the schematic presentation is the inlet (1). The arrow points to the direction, to which the feedstock is proceeding.

5

The additional preheating step (2) is following directly. The heating is indicated on the left side of said preheating step with arrows with the number (6).

The feedstock is proceeding, after the extraction of the steam and vapour (2), to the inlet of the synthesis-gas-reactor (3) and enters the closed inner space of the synthesis-gas-reactor (4).

10 The synthesis-gas-reactor is defined by its outer confinement (5).

The heating of the synthesis-gas-reactor is just generally indicated by the arrows from the left side (6). In reality, the heating is on all sides to ensure good or optimal transfer and distribution of thermal energy into the synthesis-gas-reactor and thus the feedstock.

15 The synthesis-gas that is generated in the synthesis-gas-reactor is leaving the reactor in this schematic presentation at the top left side (7).

There is an optional centrifugal-absorber (8) indicated at the top of the reactor on the right side, at the point where the extracted steam and vapour are sucked from the preheating step (2) by the compressor, pump or blower (9).

20 Directly after the compressor, pump, or blower (9) the extracted steam and vapour enter the holding-tank (10).

At the bottom of the holding-tank (10) is another compressor, pump, or blower (11), which is used to inject steam into the synthesis-gas-reactor (4), where the feedstock is reacting.

25 An additional heater or heat-exchanger (12) is shown in the duct from the holding-tank to the synthesis-gas-reactor. In the schematic-presentation there are shown three inlets for the steam and vapour at the side (13) and one injection point (14) from the bottom that may be used to generate turbulences and stable vortexes or other fluid-mechanical effects to further increase mixing of feedstock with steam inside the synthesis-gas-reactor (4).

Solid residues are leaving the reactor at the bottom (17).

30

Detailed Description of the Invention

Generally, synthesis-gas is generated by heating-up compounds, which contain carbon and let them react at high temperature with compounds, like water, which contain hydrogen that is

required for the chemical reaction that generates a carbon-hydrogen-gas-mixture. This gas mixture contains as main components: carbon-monoxide, methane, carbon-dioxide, hydrogen, steam, and then: many kinds of carbon-hydrogen compounds and the residues from the chemical-reaction. These gas mixtures are referred to in many different ways: sump-gas, water-
5 gas, bio-gas, etc. lately the term synthesis-gas is very generally used and thus will also be here the used term for those kinds of gas mixtures.

There are many ways how to realise such a chemical reaction and over time many methods have been tried and used. There are many substances that contain carbon and thus there are many
10 specific ways, often optimised for certain specific materials containing carbon-compounds. Wood-pellets are just an example of such a material, which contains a high amount of carbon-compounds and at the same time also a high amount of water. Synthesis-gas-reactors, which are meant to use wood-pellets as the main source for carbon are different in their specific layout and make, than synthesis-gas-reactors for other kinds of feedstock, for example for household-waste.
15 The invention here can be used for all those kinds of synthesis-gas-reactors, independent from the type of feedstock, the size and whether the specific synthesis-gas-reactor has been modified or optimised for certain processes or a specific feedstock. The invention can also be used independent from the kind or types of heating for the synthesis-gas-reactor, from electrical heaters to gas-fired burners, to plasma-torches, used to increase the temperature inside the
20 synthesis-gas-reactor.

Preheating Step

The feedstock of a synthesis-gas-reactor is heated inside the synthesis-gas-reactor to a temperature that starts breaking molecular-bonds in the molecules of the compounds of the
25 feedstock which enables the chemical reaction to start.

In this invention, the feedstock is also heated as in any conventional synthesis-gas-reactor, however in an additional preceding first step, before the feedstock enters the synthesis-gas-reactor, and only to a temperature that leads to at least a significant evaporation of water.

30 In a typical embodiment of this invention, the feedstock at this additional preceding first step would be heated at atmospheric pressure to a temperature of 100°C to 120°C, thus reaching in nearly all of the feedstock a temperature, which leads to the evaporation of the water, contained in the feedstock.

However, also lower temperature would lead to at least some evaporation, as higher temperature

would for sure lead to evaporation of water, contained in the feedstock.

Heating to a temperature that is at or above the evaporation-temperature of water is reached in any possible way, as it is the case today with synthesis-gas-reactors.

A possible way would be to add some heating-sleeves at the feeding-system or feeding-duct,
5 before the feedstock enters the synthesis-gas-reactor. The opening of the synthesis-gas-reactor, where the feedstock enters, has a limited cross-section, it cannot be unlimited. Thus, in nearly all cases a step is required for preparing, shredding, dosing, or otherwise enabling the feedstock to enter the synthesis-gas-reactor through its opening. Some kind of closed duct from this preparation-step to the entrance-opening of the synthesis-gas-reactor would be the best place for
10 the preheating-step. The preheating step could also be located before such a preparation-step.

As one possible example this could be in case that the feedstock contained compounds that would either react with air or steam – like potassium or lithium which can easily be found in household-waste – and are at least partly encapsulated, or to the same effect would have small
15 surface-to-volume ratios, the preheating would for safety reasons precede the preparation- and shredder-step.

Steam Generation – Vapour Generation

The heating of the feedstock to a temperature above the necessary temperature of evaporating
20 water leads to the generation of steam and other volatile compounds, forming vapours. Some compounds might have lower evaporation-temperatures as water and thus generate vapours. The evaporated water forms steam as the gaseous form of the water and is referred to hereinafter as steam.

Other compounds that also evaporate are referred to hereinafter without further specification as
25 vapour or vapours.

No filters or distillers, or other means to ensure some defined degree of purity of the generated steam and vapours from other compounds of the feedstock, are required, as the generated steam and vapours are entering the synthesis-gas-reactor in the same form and same purity, as they are
30 at the point, when they are generated.

The energy that is required to heat the feedstock to and above the evaporation temperature of the water and the energy that is required to evaporate at least a significant amount of the water in the feedstock is added from outside. The same amount of energy would be necessary for heating and thus the evaporation of water if it were without this preheating-step in the conventional way

inside the synthesis-gas-reactor.

The pre-heating-step is for the overall energy-balance of the complete system neutral. No additional energy for heating has to be provided for the synthesis-gas-reactor-system, with this new invention.

5

Extraction and Suction of Steam and Vapour

The generation of steam and vapour leads to significant additional volume, as one litre of liquid water expands to 1,673 litres of steam at atmospheric pressure.

With the mean of a compressor, blower, or pump, the steam and vapour are sucked

10 out of the preheated feedstock. By placing the suction-point at a higher location at the duct for the feedstock from the preparation-step to the feeding-entrance of the synthesis-gas-reactor, gravity will help to separate gaseous compounds from liquid and solid compounds.

In some cases an additional absorber, for example a centrifugal-absorber, or a filter might be needed, if the feedstock contains dust-like particles or liquids that form mist and droplets.

15 Even if some dust or solid or liquid compounds in small percentage would go with the suction into the separated steam and vapour, the overall function and or functionality of the complete system would not be changed or minimised.

The additional absorber or filter could be used in cases, where for example fine sand or other solids in fine form would be sucked in and end up in the holding-tank for steam and vapour,
20 where those fine solids could separate by gravity and built up layers on the bottom of the holding-tank for steam and vapour.

Also some liquids, like heavy oils, coal-tars contained in wood products or masut / mazut (a very heavy oil for some ship-Diesel-engines or impregnation of wood) could lead to such a built-up in the holding-tank, thus a separation would be an advantage in such specific cases, as it leads to
25 lower required maintenance.

Holding-Tank for Steam and Vapour

The extracted steam and vapour is fed with the same compressor, blower, or pump into a holding tank.

30 The holding-tank functions as a buffer for the steam and vapour.

The steam together with vapour and other residues in the steam-vapour-mixture is injected into the synthesis-gas-reactor according to the need for the intended chemical-reaction.

Meaning of the Holding-Tank for the Chemical-Reaction

By buffering the steam and only use the quantity, which is required by the chemical-reaction in the synthesis-gas-reactor, the process has been changed in a way that the ratio between carbon containing compounds and water can be controlled, what is otherwise not possible or only in a very limited way. From this holding-tank steam can be injected in a metered and thus quite precise amount of steam into the synthesis-gas-reactor and by this keep the chemical reaction at an optimum. As a direct consequence the so generated synthesis-gas would be much more homogeneous, even with extreme fluctuations of the water content in the compounds that enter the complete system as feedstock. In turn also the generated synthesis-gas would be as homogeneous as the injection of steam can be precise to generate a certain quality of synthesis gas.

In case of too much water-content in the feedstock to generate a certain quality and homogeneity of synthesis-gas, the steam would just be kept in the holding tank. Also the other way round, if there were not sufficient water-content in the feedstock, it could be provided for the reaction from the holding-tank.

In case there is more water in the feedstock, than necessary or advantageous for the desired chemical reaction inside the synthesis-gas-reactor, some of the steam can be released from the holding-tank through an specific outlet for such cases [*in Figure 1 this is outlet 16*], thus it would not take part in the following chemical reaction inside the synthesis-gas-reactor. By mixing this released steam with some regular tap-water outside the holding tank, the thus formed liquid water could just be discharged from the process / system.

In case the water content in the feedstock is not sufficient for a complete and or advantageous chemical reaction inside the synthesis-gas-reactor, some water in form of either steam or liquid water can be added from outside – for example in form of regular tap-water – to the holding tank.

Whether this added water is in form of steam or liquid water is for the process less relevant, as there is also an optional additional heater for the steam that follows in the process the holding-tank, as described further below [*in Figure 1 this is shown as 12*].

30

Optional Adding or Removal of Water

The extracted steam and with it some vapours of other compounds, with a lower evaporation temperature, than water, which might have been in the feedstock, are buffered in the holding-tank. It is possible if for example a set maximum-level is reached to remove some of the steam in

case it will not be needed for the reaction. This can be the case if the feedstock contains a large percentage of water, more than needed for the designed and desired chemical-reaction in the synthesis-gas-reactor.

By just using an outlet from the bottom of the holding tank it would be possible to separate vapours which are lighter, than steam by the specific density of those compounds and leave them in the holding-tank to be transferred into the synthesis-gas-reactor.

The other way round, if the feedstock would not contain sufficient amounts of water and the steam-level in the holding tank would be below a certain set minimum level in the holding-tank, additional water or steam could be added from outside to the holding tank.

Thus, the holding tank provides the means for controlling the reaction in the synthesis-gas-reactor, independent from the composition of the feedstock.

Quantitative Injection of Steam into the Synthesis-Gas-Reactor

The holding-tank is the reservoir or the steam-injection into the synthesis-gas-reactor. By measuring specific parameters of the reaction inside the reactor and / or the generated gases, it is possible to monitor the different chemical reactions in the synthesis-gas-reactor over time. If for example the amount of measured hydrogen to measured carbon-monoxide in the generated synthesis-gas is increasing above or below a certain set level this could be taken as a control-level for either decreasing or increasing the amount of the fed steam and vapour from the holding-tank. With the possibility to add the optimal amount of steam to the synthesis-gas-reactor and increase or decrease parallel to it the heating of the synthesis-gas-reactor, the chemical reaction can be kept at all times at an optimum and as a direct consequence also the generated synthesis-gas would be without fluctuations in its composition, or just minor fluctuations in its composition.

The injection of steam and vapour into the reactor can be facilitated with a compressor or pump. As the temperature of the steam before the additional heater is not that high, and as the ambient pressure in the synthesis-gas-reactors is quite low, this is possible without difficulties.

Qualitative Injection of Steam into the Synthesis-Gas-Reactor

For a chemical reaction in general and for the synthesis-gas-reactions in particular a certain amount of different compounds is necessary. Only to provide the necessary compounds is however not enough. These compounds need also to be mixed. The better the compounds are mixed, the faster and the more complete the reaction will be. If the compounds, necessary for a chemical reaction, are not mixed well, and the heat transfer to the feedstock is not fast enough,

the reaction will be incomplete and take more time, than the same reaction with well mixed compounds. Mixing of the compounds that are supposed to react in the chemical reaction, provides the contact surfaces between those compounds.

- 5 A conventional synthesis-gas-reactor has no or at best a very limited possibility of mixing the compounds for the chemical reaction.
- Additionally, the way how a synthesis-gas-reactor is conventionally operated, leads to a situation where new feedstock is fed on top of previously fed compounds. Liquids can easily go through loose feedstock and accumulate or concentrate at the bottom or lower areas inside the synthesis-
- 10 gas-reactor, thus effectively lead to de-mixing.

By injecting the steam and vapour from the holding-tank not just at one or at few points, but by using those injection-points like jets at advantageous points, for example, where the feedstock is heated most, or by creating a stable vortex, a far efficient and reliable mixing can be achieved

15 than in a conventional synthesis-gas-reactor.

It is also possible to position the injection-points in a way to generate turbulences, vortexes and other fluid-mechanical effects, thus increasing the mixing between the heated feedstock in the synthesis-gas-reactor and the fed steam and vapour.

20 Optional Additional Heating of the Separated Steam and Vapour

It is possible to add an additional heating step after the holding-tank and thus additionally heat the steam and vapour before injecting the steam and vapour into the synthesis-gas-reactor. This would not lead to more energy-consumption, as these compounds would, if not heated additionally, be heated inside the synthesis-gas-reactor.

- 25 By heating the steam and vapour before injection, best to the temperature required to start the chemical reaction, for example in case of organic compounds like wood or household-waste this would be in a range of 400°C to 800°C – or even above this required temperature – for example to a range from 800°C to 1,400°C –, would lead to an additional increase of reaction-speed. The heated steam and vapour can reach inside the synthesis-gas-reactor the feedstock with a much
- 30 larger surface area and thus heat the feedstock faster than the heating coming from outside the synthesis-gas-reactor.

The steam would then, additionally to the heating of the synthesis-gas-reactor from outside, also heat the compounds inside the synthesis-gas-reactor.

By heating a fraction of the reacting compounds – the steam and with it some vapours – to a

much higher temperature, than the average temperature in the synthesis-gas-reactor, leads also not to a higher energy-consumption of the complete reaction, as the thermal-energy of the water replaces the otherwise required thermal-energy of the indirect heating of the other fraction of the feedstock by the heating elements of the synthesis-gas-reactor, heating the synthesis-gas-reactor
5 from outside.

Optional Increase of Pressure of the injected Steam and Vapour

It is possible to add an additional step after the holding-tank before the injection of the steam and vapour into the synthesis-gas-reactor to increase the pressure of the injected steam and vapour
10 and thus generate additional fluid-mechanical effects that increase and improve the mixing of steam and feedstock further.

Good Mixing leads to an Increased Reaction Speed and more Complete Chemical Reactions lead to higher efficiency and better use of the reactor-volume.

15 The last two points show that the preheating of the feedstock, the extraction of steam and some vapours, the separation in a holding-tank and the qualitative and quantitative best injection of the extracted steam leads to a better, faster and more complete chemical reaction.

The faster reaction by itself leads to a better use of the volume of the synthesis-gas-reactor. Thus, either the reactor could be smaller with the same amount of feedstock per time or the capacity
20 and thus the yield of generated synthesis-gas could increase for the same size.

Also, the more complete reaction due to increased mixing leads to a better use of the volume of the synthesis-gas-reactor.

Both these last two effects combined lead thus to either a smaller reactor-size or a higher yield of generated synthesis-gas. Both translate into lower investment-costs.
25

Also, a smaller size of the synthesis-gas-reactor for the same yield leads to smaller total heat-losses, as the surfaces of a smaller reactor are smaller than for a larger reactor with the same yield.

A homogeneous reaction in the synthesis-gas-reactor with the described invention leads also to a
30 constant quality of the generated synthesis-gas, what is also a commercial advantage as such a homogeneous synthesis-gas can be used more easily and for more purposes.

Claims

1. A reactor system for the generation of a combustible gas-mixture of carbon-monoxide, methane, carbon-dioxide, hydrogen, water, and other compounds from a provided feedstock of compounds containing carbon and water, said reactor system comprising:
a closed reactor;
means of feeding said feedstock through at least one designated opening into said closed reactor;
heating means for heating said compounds inside said closed reactor from outside said closed reactor;
at least one suction means;
at least one holding tank;
at least one other means for receiving or taking and injecting generated steam and other generated vapours from said holding tank,
wherein said heating means is configured for heating said feedstock in at least one preheating step that precedes opening said closed reactor for feeding said feedstock to a temperature that evaporates water contained in said feedstock,
wherein said heating of said compounds inside said closed reactor is made to a temperature that starts a reaction and generates said gas-mixture,
said at least one suction means is configured to suck generated steam and other generated vapours from said feedstock by said preheating step in at least one suction step,
wherein the sucked said generated steam and other generated vapours are forwarded to and stored in said at least one other means to receive or take and inject a stored said generated steam and other generated vapours from said holding-tank into said closed reactor,
wherein said at least one other means for receiving or taking and injecting said generated steam and other generated vapours from said holding tank are put up and operated additionally and parallel to said closed reactor.
2. The reactor system according to claim 1, further comprising a feeding duct for feeding said feedstock to an inlet of said closed reactor in form of a sleeve that surrounds at least partially either a, the, or some of feeding ducts to said closed reactor,
wherein said feeding of said feedstock into said inlet of said closed reactor is combined with said at least one preheating step.

3. The reactor system according to claim 1 or 2, further comprising at least one pump, a compressor or blower used to suck out said steam and vapour generated in said preheating step and forward it to at least one said holding tank.
- 5 4. The reactor system according to any one of claims 1 to 3, wherein at least one of said holding tanks comprises at least one means to take in steam or water from outside of said closed reactor and / or release steam from said closed reactor.
- 10 5. The reactor system according to any one of claims 1 to 4, wherein said at least one holding tank allows the separation of steam and vapour by taking the steam out from middle of said holding tank below a separation-line, where gravity separates lighter vapour from heavier steam.
- 15 6. The reactor system according to any one of claims 1 to 5, wherein said steam is further heated in at least one additional heating step after introducing said steam into said at least one holding tank and before injecting said steam into said closed reactor.
- 20 7. The reactor system according to any one of claims 1 to 6, further comprising means to increase pressure of said steam for injection of said steam into said closed reactor for said at least one injection of said steam from said at least one holding tank into said closed reactor, to enable additional mixing of said steam additionally pressurised with feedstock inside said closed reactor.
- 25 8. The reactor system according to any one of claims 1 to 7, wherein said at least one of the injections of said steam from said holding tank into said closed reactor are at specific geometrical points inside said closed reactor to induce stable internal vortex and to optimise mixing and chemical reaction of said steam and feedstock inside said closed reactor.
- 30 9. The reactor system according to any one of claims 1 to 8, wherein said at least one of the injections of said steam from said holding tank into said closed reactor is in a range of temperature of 800°C-1400°C to optimise mixing and chemical reaction of said steam and feedstock inside said closed reactor.
- 35 10. The reactor system according to any one of claims 1 to 9, wherein said at least one injection of said heated steam from said holding tank into said closed reactor is used and

thus positioned to generate streaming-mechanical or fluid-mechanical effects inside said closed reactor to increase mixing of compounds participating in a chemical reaction inside said closed reactor.

- 5 11. The reactor system according to any one of claims 1 to 10, wherein location at which said generated steam and other generated vapours are sucked in is at an elevated area of the preheating step in order that a smaller quantity of solid particles and dust-like particles or liquids that form mist and droplets are sucked into said at least one means to suck in said generated steam and other generated vapours, due to lower density at a higher location.
- 10 12. The reactor system according to any one of claims 1 to 11, further comprising at least one absorber, to separate solid particles and dust-like particles or liquids that form mist and, which are sucked into a duct leading to said at least one means to suck in said generated steam and other generated vapours, thus reducing quantity of such
- 15 solid particles and similar loose compounds like droplets in a separated said generated steam and other generated vapours.
13. The reactor system according to any one of claims 1 to 12, further comprising at least one heating element for heating said feedstock inside said closed reactor.
- 20 14. The reactor system according to any one of claims 1 to 13, further comprising at least one plasma torch or burner jet for heating said feedstock inside said closed reactor.

25