Method and apparatus for the manufacturing of non-energent biochar~~coal~~ with thermal treatment

The invention relates to a method and an apparatus as set forth in the preambles of independent claims directed thereto for manufacturing, with thermal treatment, ~~bio-coal which is non-energent, i.e.~~biochar which is functional e.g. as a so-called carbon sink.

The use of a traditional Thompson Converter type apparatus is based on supplying to-be-processed feedstock to one or more screw conveyors present in a process space included in the apparatus, the to-be-processed feedstock being carried by said conveyor/s in a longitudinal direction of the process space while being heated indirectly at the same time. The feedstock inside the conveyors, carbonized by heat transferring from the latter to the to-be-processed feedstock, is discharged from a second end of the conveyors onto a collecting conveyor which delivers the carbonized feedstock out of the process space. In such a solution, the pyrolysis gas generated inside the screw conveyors migrates traditionally in a traveling direction of and along with the to-be-processed feedstock from a discharge end of the screw conveyors into a collection chamber and therefrom further along a connecting conduit into a combustion furnace below the screw conveyor space for burning. Flue gas discharges from the combustion furnace into the screw conveyor space, wherein the heat contained in the flue gas is delivered by convective heat transfer to the screw conveyors prior to being removed from the process space by way of a discharge unit.

Activating the discussed type of apparatus requires that the combustion furnace be heated in its entirety, e.g. with a solid fuel combustible therein, to a sufficiently high temperature prior to starting the actual carbonization process for enabling the pyrolysis gas to burn and thereafter the process to function in a so-called self-sustaining manner. Therefore, the discussed solution is laborious and slow, especially in terms of initial startup.

Solutions of the foregoing type are also available at present in such implementations that the combustion furnace is provided e.g. with a kerosene burner for maintaining an auxiliary flame, one further implementation being such that pyrolysis gas, conveyed in a direction opposite to a traveling direction of the screw conveyor arrangement, is conducted into a combustion furnace to be burned with the aforementioned burner flame.

The most notable drawback at present in sets of equipment of the foregoing type is a modest "volume efficiency [W/m^3]" thereof as a result of indirect or convective heat transfer applied in the heating of screw conveyors. First of all, this prolongs considerably a cold start time for the apparatus before the actual continuous carbonization process can be started. On the other hand, one essential drawback is that the preheating of a furnace space requires either the use a solid fuel for quite a long period of time or else the use of a continuous auxiliary flame produced with a separate fuel for enabling the pyrolysis gas to be burned. Therefore, the

current technology is not able to provide a carbon separation process that could be implemented with reasonable investment and operating costs.

For example, the international patent application WO 2011/004073 discloses a method for separating carbon by thermal treatment, in which method matter to be processed is brought by a feed arrangement to a conveyor arrangement connected to a process space that is substantially of a Thompson Converter type. The matter to be processed is made to move in the process space in longitudinal direction thereof by means of a conveyor arrangement closed in relation to the space, whereby pyrolysis gas formed by heat transfer from the process space into the matter to be processed contained in the conveyor system is conveyed inside the conveyor system in a direction opposite to the conveying direction and out of the conveyor system for burning the same in a combustion space provided in the process space. The formed flue gas is discharged from the process space by means of a discharge arrangement and thermally treated matter is discharged by means of discharge elements from the conveyor arrangement for further processing. In this respect, the pyrolysis gas is first of all burned by a continuous gas burner arrangement and, secondly, heat transfer of the conveyor system in the process space is carried out substantially by direct radiation from the flame of the gas burner arrangement and from the walls of the combustion space.

However, even this solution does not as such enable production of ~~non-energent biocoal~~ biochar in such a way

that PAH compounds contained therein would be at a sufficiently low level.

It is an objective of the present method and apparatus according to the invention to provide a decisive improvement regarding the aforementioned problems and to thereby substantially raise the available prior art. In order to accomplish this objective, the method and apparatus of the invention are primarily characterized by what has been presented in the characterizing clauses of independent claims directed thereto.

The most important benefits obtained by a method and apparatus of the invention should be noted to include the simplicity and efficacy of the operating principle thereof, equipment stock suitable for the implementation thereof, and the use thereof. By virtue of the invention it is possible to produce ~~non-energent biocoal~~biochar containing a very small amount of PAH compounds, in the best case none at all, which can be accomplished by thermally treating a to-be-processed feedstock inside a conveyor system through the utilization of water vapor generated from water delivered into the conveyor system. The invention is implementable in a technically extremely simple and efficient manner by using, first of all, a continuously operating conveyor arrangement provided with a supply and discharge element that is substantially gastight with respect to the environment. It is thereby that oxygen supply into the pyrolysis gas within the conveyor arrangement can be prevented, whereby said gas, as it travels towards a supply end of

the conveyor arrangement in a counterflow principle relative to the to-be-processed feedstock traveling inside the same in a longitudinal direction, cools down effectively as the heat therein transfers into the to-be-processed feedstock moving in an opposite direction, thus enabling the pyrolysis gas to be conducted at an ideal temperature to the gas burner for combustion.

The utilization of a sufficiently large-volume combustion chamber in the process space enables, first of all, the combustion of flue gases with a two-second dwell time at a temperature higher than 850°C as required by the EU waste incineration derivative. In addition, the conditions presently existing in a rear section of the combustion chamber are favorable for an SNCR (Selective Non-catalytic Reduction) nitrogen reaction, i.e. temperature of 800-1100°C and oxidizing atmosphere.

The apparatus constructed with a method of the invention has an optimal volume efficiency as the heat transfer to a conveyor arrangement takes place in the process space from the flame of a gas burner/burners with direct radiation heat (radiation heat transfer being proportional to the fourth power of temperature), which fist of all expedites the startup of a ~~non-energent biocoal~~ biochar producing process as the conveyor arrangement's surface temperatures increase with direct radiation from a gas flame considerably more rapidly than with convective heat transfer. Hence, by virtue of the invention it is therefore possible to assemble an apparatus, which is considerably smaller in size and more compact than its presently available counterparts, and whose investment,

service and maintenance costs are naturally also decisively more affordable than those of traditional solutions.

Other preferred embodiments for a method and apparatus of the invention are presented in dependent claims directed thereto.

In the subsequent description, the invention will be reviewed in detail with reference to the accompanying drawing, which depicts a general operating principle for the apparatus functioning with a method of the invention.

The invention relates first of all to a method for manufacturing, with thermal treatment, ~~biocoal~~ biochar which is ~~non-energent, such as~~ functional as a ~~heat~~ carbon sink, said method comprising introducing a to-be-processed feedstock x with supply elements 1a into the interior of a conveyor arrangement 3, which is present in a Thompson Converter type process space 2 and closed relative thereto, for moving the to-be-processed feedstock x in the process space 2 in a longitudinal direction s of the process space, whereby a pyrolysis gas y, generated from the to-be-processed feedstock x present in the conveyor arrangement 3 as a result of heat transferring thereto from the process space, is conducted away from the conveyor arrangement for burning the same in a combustion chamber 4 of the process space. A resulting flue gas y' is removed from the process space by way of a discharge arrangement 5 and a produced ~~non-energent biocoal~~ biochar x' is removed from the conveyor

arrangement with discharge elements 1b for further processing. Referring particularly to the attached exemplary process flow chart, the pyrolysis gas y is burned with a most preferably continuously operating gas burner arrangement 7 and heat transfer for the conveyor arrangement 3 in the process space 2 is conducted with substantially direct radiation from a flame of the gas burner arrangement 7 and from walls of the combustion chamber 4. In addition, the pyrolysis gas y is conducted within the conveyor arrangement 3 in a counterflow relative to the longitudinal direction s of the process space towards a supply end I of the conveyor arrangement for transferring the heat present in the pyrolysis gas y into the to-be-processed feedstock x moving in the longitudinal direction s of the process space and for delivering the cooled pyrolysis gas y to the gas burner arrangement 7. The amount of PAH compounds contained in the to-be-produced ~~non-energent biocoal~~ biochar x' is reduced/eliminated by means of water vapor z' by supplying water z into the interior of the conveyor arrangement 3, the water z being conducted into the interior of the conveyor arrangement 3 from its discharge end II for carrying the water vapor flow z', jointly with the pyrolysis gas y, in a counterflow relative to the longitudinal direction s of the process space towards the conveyor arrangement's supply end I.

In reference to the attached process flow chart, it is moreover particularly important in applying a method of the invention that the removal of the pyrolysis gas y ~~y'~~ takes place in the longitudinal direction s of the pro-

cess space 2 prior to the supplying 1a the to-be-processed feedstock x. Conducting the aforementioned operations in a wrong order undermines substantially the usability of the process, whereby for example the pipes involved in the aforementioned operations become easily clogged and, when running the process at high capacity, the mass is able to rise into the gas pipe. It is further particularly important for the sound operation of a method of the invention that the surface level of a to-be-processed feedstock inside the conveyor arrangement be controlled carefully, which is absolutely necessary especially from the standpoint of managing pressure and tar accumulation. Another aspect of major importance is the management of pyrolysis gas in terms of its temperature and moisture because, without water supply, the gas pipes will be quickly clogged in practice as long as the to-be-processed feedstock is dry. The moistening of to-be-processed feedstock is in practice a challenging operation, further resulting in the process losing some of its productive capacity, which is avoided by supplying water mist z, according to the attached process flow chart, into the pyrolysis gas y ~~y'~~ for the management of its moisture and temperature.

It is by conducting a water vapor flow z', jointly with the pyrolysis gas y, in a counterflow relative to the longitudinal direction s of the process space towards the supply end I of the conveyer arrangement that there is provided as effective a process as possible between water vapor z' and to-be-processed feedstock, whereupon, in a further preferred embodiment of the method, the to-be-produced ~~non-energent biocoal~~ biochar x' is cracked

and cooled by the action of water vapor prior to its removal from the conveyor arrangement 3.

In a further preferred embodiment for a method of the invention, the to-be-processed feedstock x is treated in the process space 2 with the conveyor arrangement 3, which is at excess pressure relative thereto and provided with the supply and discharge elements 1a, 1b that are substantially gastight relative to the environment, this being preferably implemented by using one or more electric motor-driven and steplessly adjustable, such as variable-speed driven, screw conveyors 3a or the like.

When supplying the conveyor arrangement 3 with to-be-processed feedstock, it is possible to utilize e.g. the method and supply system according to Finnish patent No. 119125 especially for implementing the supply of to-be-processed feedstock from above to occur first of all in a continuous manner and, on the other hand, in such a way that process gases cannot escape in an uncontrolled manner from inside the conveyor arrangement or from the process space into the environment.

In yet another preferred embodiment, the conveyor arrangement 3 is most effectively heated immediately after its introduction into the process space 2 with one or more gas burners 7; 7a mounted on an entrance wall 2a of the process space in a co-directional relationship with the conveyor arrangement.

In a further preferred embodiment, the transport capacity of a conveyor arrangement 3, such as one or more

screw conveyors 3a, can be changed in the longitudinal direction s of the process space especially for reducing the layer thickness of the to-be-processed feedstock x from the supply end I of the conveyor arrangement 3 towards its discharge end II. Hence, the conveyor arrangement 3 is preferably implementable e.g. with a screw conveyor 3a provided at its upstream end with smaller pitch and at its downstream end with a larger pitch.

It is further possible to implement the air supply for a gas burner arrangement 7, such as for one or more parallel gas burners 7a, with a separate combustion air fan. On the other hand, it is further possible, in connection with the gas burner 7a, to also preferably make use of e.g. an ejector fan for sucking the pyrolysis gas y by way of an ejector nozzle into the gas burner.

In a further preferred embodiment, it is also possible with a method of the invention to process mutually dissimilar feedstocks x, w by bringing the same, as indicated e.g. in the attached process flow chart, into the conveyor arrangement by separate supply elements 1a, the feedstocks delivered therefrom blending with each other while being pushed by the screw conveyor 3a towards the process space. In this context, it is naturally also possible to proceed in such a manner that various feedstocks are mixed with each other in a separate mixing space and delivered with a single supply element into the conveyor arrangement 3.

In yet another preferred embodiment, there is executed in the process space a nitrogen reduction, carried out

e.g. with a so-called SNCR (Selective Non-catalytic Reduction) method, by using an additional nozzle arrangement 1s for supplying the combustion chamber 4 with an ammonia-containing medium, such as urea spray, aqueous ammonia solution or the like. By placing the aforementioned nozzle arrangement at a point marking the end of a gas flame burning zone, the medium sprayed by way of the nozzle arrangement evaporates, whereby the resulting ammonia is blended and has time to effect on flue gases long enough for a meaningful nitrogen reaction. Additionally, in a method of the invention, there is further ensured, preferably e.g. with a lambda sensor, that the combustion is permanently provided with excess air.

In a further preferred embodiment of the invention, the supply of additives into the ~~non-energent~~ to-be-produced ~~biocoal~~ biochar x' is implemented by admixing with the water z to be delivered into the conveyor arrangement 3.

On the other hand, the invention relates also to an apparatus for implementing the aforementioned method, the apparatus including:

- supply elements 1a for introducing a to-be-processed feedstock x into the interior of a conveyor arrangement 3 present in and closed relative to a Thompson Converter type process space 2 for moving the to-be-processed feedstock x in the process space 2 in a longitudinal direction s of the process space,
- a flow arrangement 8 for conducting a pyrolysis gas y, generated from the to-be-processed feedstock x present in the conveyor arrangement 3 as a result of heat transferring thereto from the process space, away from the

conveyor arrangement for burning the same in a combustion chamber 4 of the process space,

- a discharge arrangement 5 for removing a resulting ~~fuel~~ flue gas y' from the process space,
- discharge elements 1b for the removal of a produced ~~non-energent biocoal~~ biochar x' from the conveyor arrangement for further processing, and
- a most preferably continuously operating gas burner arrangement 7 for burning the pyrolysis gas y,

whereby the heat transfer for the conveyor arrangement 3 in the process space 2 is adapted to occur with substantially direct radiation from a flame of the gas burner arrangement 7 and from walls of the combustion chamber 4. In addition, the flow of the pyrolysis gas y within the conveyor arrangement 3 takes place in a counterflow towards a supply end I of the conveyor arrangement for transferring the heat present in the pyrolysis gas into the to-be-processed feedstock x moving in an opposite direction s and for delivering the cooled pyrolysis gas y to the gas burner arrangement 7. The apparatus further includes a supply arrangement 1c for conducting water z into the interior of the conveyor arrangement 3, for reducing/eliminating by means of water vapor z' the amount of PAH compounds contained in the to-be-produced ~~non-energent biocoal~~ biochar x', the supply arrangement 1c being adapted to conduct the water into the interior of the conveyor arrangement 3 essentially to a discharge end II of the conveyor arrangement for carrying a water vapor flow z', jointly with the pyrolysis gas y, in the longitudinal direction s of the process space towards the conveyor arrangement's supply end I.

Referring to the attached process flow chart, it is in a preferred embodiment of the invention that a discharge pipe 1a' for pyrolysis gas is disposed in a longitudinal direction upstream of the to-be-processed feedstock supply arrangement 1a. In the attached process flow chart there is further presented a supply arrangement 1e for delivering water mist into the pyrolysis gas y~~y'~~ for adjusting its moisture and temperature. In addition, the apparatus preferably includes a cooling arrangement 1d for cooling the produced ~~non-energent biocoal~~ biochar x' with a water/water vapor z' circulation implemented preferably on the counterflow principle.

In a further preferred embodiment of the apparatus, it comprises a conveyor arrangement 3, which is housed in the process space 2, is at excess pressure relative thereto, and is provided with the supply and discharge elements 1a, 1b substantially gastight relative to the environment, the benefits associated therewith having already been described above.

It is obvious that the invention is not limited to the embodiments presented or described above, but can be varied within the basic concept of the invention so as to comply with given intended uses and applications. Accordingly, it is first of all clear that, with regard to the combustion process, the method can be conducted by making use of per se conventional control technology and automation e.g. with oxygen analyzers and temperature sensors needed in the combustion of pyrolysis gas and/or by using e.g. a preheating burner. Respectively,

for the processing of to-be-processed feedstock it is possible to provide the screw conveyor arrangement with necessary monitoring arrangements for enabling optimal carbonization and final temperature e.g. by stepless regulation of the screw conveyor arrangement's operation. It is naturally possible that the apparatus applying a method of the invention be preferably further provided e.g. with optical flame monitoring analyzers and e.g. with a "torch tube" 12 according to the drawings, which is connected to the conveyor arrangement and by which the pyrolysis gas can be released, if necessary, by combustion with a separate burner, the torch tube thereby functioning as a relief valve enabling a rapid emergency switch-off of the apparatus.

Claims

1. A method for manufacturing, with thermal treatment, ~~biocoal~~ biochar which is ~~non-energent, such as~~ functional as a ~~heat~~ carbon sink, said method comprising ~~introducing~~ supplying a to-be-processed feedstock (x) with supply elements (1a) into the interior of a conveyor arrangement (3), the conveyor arrangement (3) being ~~which is~~ present in a process space (2) of a Thompson Converter ~~-~~type, ~~process space (2) and~~ the said conveyor arrangement (3) being enclosed relative to the process space (2) ~~thereto~~, for moving the ~~to-be-~~processed feedstock (x) in the conveyor arrangement (3) through the process space (2) in a longitudinal direction (s) of the process space, whereby a pyrolysis gas (y), generated from the ~~to-be-processed~~ feedstock (x) ~~present~~ being processed in the conveyor arrangement (3) as a result of heat transferring thereto from the process space (2), is being conducted away from the conveyor arrangement for burning the ~~same~~ pyrolysis gas (y) with a continuously operating gas burner arrangement (7) in a combustion chamber (4) of the process space (2), wherein the heat transfer for the conveyor arrangement (3) in the process space (2) is conducted with radiation from a flame of the gas burner arrangement (7) and from walls of the combustion chamber (4) and whereby a resulting flue gas (y') is being removed from the combustion chamber (4) of the process space (2) by way of a discharge arrangement (5) and a produced ~~non-energent biocoal~~ biochar (x') is being removed from the conveyor arrangement (3) with discharge elements (1b) for further processing, ~~whereby the pyrolysis gas (y) is burned with a most preferably continuously operating gas burner arrangement (7) and~~

~~heat transfer for the conveyor arrangement (3) in the process space (2) is conducted with substantially direct radiation from a flame of the gas burner arrangement (7) and from walls of the combustion chamber (4),~~ and whereby the pyrolysis gas (y) is conducted within the conveyor arrangement (3) in a counterflow relative to the longitudinal direction (s) of the process space towards a supply end (I) of the conveyor arrangement (3) for transferring the heat present in the pyrolysis gas (y) into the to-be-processed feedstock (x) moving in the longitudinal direction (s) of the process space and for delivering the cooled pyrolysis gas (y) to the gas burner arrangement (7), **characterized** in that the water (z) is being supplied into the interior of the conveyor arrangement (3), generating water vapor (z'), ~~amount of PAH compounds contained in the to-be-produced non-energent biocoal (x') is reduced/eliminated by means of water vapor (z') by supplying water (z) into the interior of the conveyor arrangement (3),~~wherein the water (z) is being conducted into the interior of the conveyor arrangement (3) from its discharge end (II) for generating water vapor (z') therein, ~~carrying~~ the water vapor flow (z')~~,~~being carried jointly with the pyrolysis gas (y)~~,~~ in a counterflow relative to the longitudinal direction (s) of the process space towards the conveyor arrangement's supply end (I) to reduce the amount of PAH compounds in the processed biochar (x').

2. The method according to claim 1, **characterized** in that pyrolysis gas (y~~y'~~) to be produced is removed in the longitudinal direction (s) of the process space (2) prior to supplying (1a) the to-be-processed feedstock (x).

3. The method according to claim 1 or 2, **characterized** in that the ~~to-be-~~produced ~~non-energent biocoal~~ biochar (x') is cracked and cooled by the action of water vapor (z') prior to its removal from the conveyor arrangement (3).

4. The method according to any of the preceding claims 1-3, **characterized** in that the to-be-processed feedstock (x) is treated in the process space (2) with the conveyor arrangement (3), which is at excess pressure relative thereto and provided with the supply and discharge elements (1a, 1b) that are substantially gastight relative to the environment.

5. The method according to any of the preceding claims 1-4, **characterized** in that the supply of additives into the ~~non-energent~~ to-be-produced ~~biocoal~~ biochar (x') is implemented by admixing with the water (z) to be delivered into the conveyor arrangement (3).

6. An apparatus for manufacturing ~~non-energent biocoal~~ biochar with thermal treatment, said apparatus including:

- supply elements (1a) for ~~introducing~~ supplying a to-be-processed feedstock (x) into the interior of a conveyor arrangement (3) present in ~~and closed relative to a Thompson Converter type~~ a process space (2), said process space being of a Thompson Converter type and said conveyor arrangement (3) being enclosed relative to the process space (2) for moving the to-be-processed feedstock (x) in the conveyor arrangement (3) through the

process space (2) in a longitudinal direction (s) of the process space (2),

- a flow arrangement (8) for conducting a pyrolysis gas (y), generated from the ~~to-be-~~processed feedstock (x) ~~present~~ processed in the conveyor arrangement (3) as a result of heat transferring thereto from the process space (2), away from the conveyor arrangement (3) for burning the same in a combustion chamber (4) of the process space,
- a discharge arrangement (5) for removing a resulting ~~fuel~~ flue gas (y') from the combustion chamber (4) of the process space (2),
- discharge elements (1b) for the removal of a produced ~~non-energent biocoal~~ biochar (x') from the conveyor arrangement (3) for further processing, and
- a ~~most preferably~~ continuously operating gas burner arrangement (7) for burning the pyrolysis gas (y),

whereby the heat transfer for the conveyor arrangement (3) in the process space (2) is adapted to occur with ~~substantially direct~~ radiation from a flame of the gas burner arrangement (7) and from walls of the combustion chamber (4), and whereby the pyrolysis gas (y) is conducted within the conveyor arrangement (3) in a counterflow towards a supply end (I) of the conveyor arrangement (3) for transferring the heat present in the pyrolysis gas (y) into the to-be-processed feedstock (x) moving in an opposite direction (s) and for delivering the cooled pyrolysis gas (y) to the gas burner arrangement (7), **characterized** in that the apparatus includes a supply arrangement (1c) for conducting water (z) into the interior of the conveyor arrangement (3) to generate water vapor (z'), ~~for reducing/eliminating by means of water vapor (z') the amount of PAH compounds contained in the~~

~~to-be-produced non-energent biocoal (x')~~, said supply arrangement (1c) being adapted to conduct the water (z) essentially to a discharge end (II) of the conveyor arrangement (3) to generate water vapor therein for carrying the water vapor flow (z')~~,~~ jointly with the pyrolysis gas (y), in a counterflow relative to the longitudinal direction (s) of the process space towards the conveyor arrangement's supply end (I) to reduce the amount of PAH compounds contained in the produced biochar (x').

7. The apparatus according to claim 6, **characterized** in that the supply arrangement (1c) is adapted to discharge the to-be-produced pyrolysis gas (y~~y'~~) in the longitudinal direction (s) of the process space (2) prior to supplying (1a) the to-be-processed feedstock (x).

8. The apparatus according to claim 6 or 7, **characterized** in that it comprises a conveyor arrangement (3), which is housed in the process space (2), is at excess pressure relative thereto, and is provided with the supply and discharge elements (1a, 1b) substantially gastight relative to the environment.

METHOD AND APPARATUS FOR THE MANUFACTURING OF NON-ENERGENT BIOCHARCOAL WITH THERMAL TREATMENT

(57) Abstract

The invention relates to a method and an apparatus for manufacturing, with thermal treatment, biocoal biochar which is non-energent, such as functional as a heat carbon sink, by using a conveyor arrangement (3) housed in an essentially Thompson Converter type process space (2). A to-be-processed feedstock (x) is conveyed in the process space (2) with the conveyor arrangement (3), which is closed relative thereto, in a longitudinal direction (s) of the process space, whereby a pyrolysis gas (y), generated from the to-be-processed feedstock (x) present inside the conveyor arrangement (3) as a result of heat transferring from the process space thereto, is conducted into a combustion chamber (4) included in the process space for burning the gas, a thereby generated flue gas (y') being removed from the process space by way of a discharge arrangement (5) and a resulting non-energent biocoal biochar (x') being removed from the conveyor arrangement for further processing. The amount of PAH compounds contained in the to-be-produced non-energent biocoal biochar (x') is reduced/eliminated by means of water vapor (z') by deliv-

ering water (z) into the interior of the conveyor arrangement (3), said water being conducted into the interior of the conveyor arrangement (3) from its discharge end (II) for carrying the water vapor flow (z'), jointly with the pyrolysis gas (y), in a counterflow relative to the longitudinal direction (s) of the process space towards the conveyor arrangement's supply end (I).