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(54) Title: TORREFACTION APPARATUS

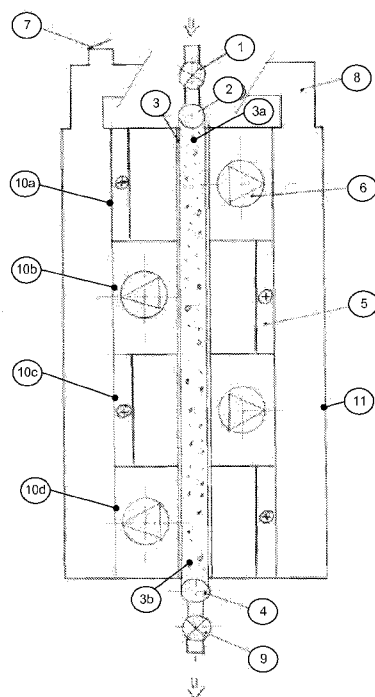


Fig. 1

(57) Abstract: According to one embodiment, the application relates to a torrefaction apparatus, comprising a conveying channel (3) adapted to pass a material to be torrefied, said conveying channel comprising openings for enabling torrefaction and being divided into at least one zone (10a, 10b, 10c, 10d), and torrefaction means (5, 6) adapted to transfer thermal energy into a torrefying gas used for torrefaction essentially in a cross-flow by way of its openings. In addition, the torrefaction apparatus is provided with measuring means adapted to measure temperature of the flowing torrefying gas in the vicinity of the conveying channel, and with control means which, jointly with the torrefaction means, enable a zone-specific adjustment of the torrefying gas temperature and flowing direction on the basis of measurement data received from the measuring means.



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TORREFACTION APPARATUS

Technical field

The application relates generally to a torrefaction apparatus.

Background

- 5 Torrefaction (thermal process) involves heating biomass, such as wood chips, saw or cutter dust, logging residue, straw or peat, in oxygen-free conditions to a temperature of 200-300 °C. In terms of processing temperature, torrefaction surpasses drying (evaporation), but falls clearly short of pyrolysis.

- 10 Torrefaction is preceded by the drying of biomass. Torrefaction itself enables some of the lignin, as well as volatile components and extracts, e.g. sugar, to be removed from biomass, i.e. torrefaction is analogous to thermal treatment of sawn timber. Torrefied biomass without densification is lighter than the original, produces less smoke when burning, and has lesser-than-original particulate emissions. Torrefaction particularly improves the heating value of biomass,
15 typically by about 10-22%. In addition, the increased hydrophobicity improves the preservability of a resulting product. Torrefied biomass is generally darker than the original.

- Torrefied biomass has a solid carbon content of about 25% and an energy content of about 90% with respect to the original. Torrefied biomass can also
20 be pelletized, which is not the case with pyrolyzed biomass. Torrefied biocoal is suitable as fuel for a coal-fired power plant and relatively easy to store. Prior to torrefaction, biomass must be subjected to pre-drying for a moisture content of not higher than 10-20%.

At present, biomass is typically torrefied in various types of reactors.

- 25 For example, patent application US 2011179700 A1 discloses a system for torrefaction of biomass, said system including a preheater, a torrefaction reactor, and a furnace. The preheater is configured to heat biomass from a first temperature to a desired torrefaction temperature. The torrefaction reactor is configured to maintain heating of the biomass at the desired torrefaction temperature
30 for a desired period of time to generate torrefied biomass. The furnace is

configured to generate and convey heat to the preheater and the torrefaction reactor.

- Patent US 8105400 B2 discloses a process for treating biomass, wherein the biomass is heated to a torrefying temperature in a low-oxygen atmosphere in a torrefaction reactor, wherein the biomass is converted into torrefied biomass. The biomass with a certain residual moisture is fully dried in a drying chamber by evaporation of the residual moisture. The torrefaction reactor comprises a torrefying chamber in which the torrefaction of the dried biomass is carried out. The biomass is conveyed through the torrefaction reactor in a transport direction. Drying of the biomass in the drying chamber is carried out by introducing into it a hot drying gas that flows through the drying chamber in co-current with the biomass. Torrefaction of the biomass is carried out by introducing into it a hot torrefying gas that flows through the torrefying chamber in counter-current to the biomass.
- The prior known torrefaction methods and equipment are relatively complicated, inefficient, and expensive.

Summary

It is one objective of the invention to eliminate some of the prior art problems and to provide a structurally simple and efficient torrefaction apparatus.

- The one objective of the invention is attained with a torrefaction apparatus of claim 1 and a torrefaction method of claim 9.

- According to one embodiment, the torrefaction apparatus has a conveying channel adapted to pass a material to be torrefied, said conveying channel comprising openings for enabling torrefaction and being divided into at least one zone, and torrefaction means adapted to transfer thermal energy into a torrefying gas used for torrefaction and to introduce the torrefying gas into the conveying channel essentially in a cross-flow by way of its openings. The torrefaction apparatus is further provided with measuring means adapted to measure temperature of the flowing torrefying gas in the vicinity of the conveying channel, and with control means which, jointly with the torrefaction means, enable a zone-specific adjustment of the torrefying gas temperature and flowing direction on the basis of measurement data received from the measuring means.

According to one embodiment, the torrefaction method comprises passing a material to be torrefied in a conveying channel, which comprises openings for enabling torrefaction and which is divided into at least one zone, and using torrefaction means to transfer thermal energy into a torrefying gas used for torrefaction, and using the torrefaction means to introduce the torrefying gas into the conveying channel essentially in a cross-flow by way of its openings. The method further comprises the use of measuring means for measuring temperature of the flowing torrefying gas in the vicinity of the conveying channel and the use of control means and the torrefaction means for adjusting the temperature and flowing direction of the torrefying gas in a zone-specific manner on the basis of measurement data received from the measuring means.

Other embodiments are presented in the dependent claim.

Description of the figure

Fig. 1 shows a torrefaction apparatus 11 in a structural cross-section.

The apparatus 11 is intended for the drying and/or torrefaction of a material to be torrefied, for example biomass, for example wood chips, wood dust, straw or peat.

In order to pass biomass therethrough, the apparatus 11 is provided with a permanently upright conveying channel 3 with openings (not shown) in its walls. The tall, narrow and long, duct type conveying channel 3 - and the apparatus 11 as a whole - is divided in vertical direction into at least one zone 10a, 10b, 10c, 10d. Fig. 1 depicts four zones 10a, 10b, 10c, 10d, which can be partitioned for example with intact solid walls to isolate the zones 10a, 10b, 10c, 10d from each other.

By virtue of the upright conveying channel 3, the apparatus 11 is highly space-efficient. In addition, it can be located outdoors, whereby the apparatus 11 does not even require a building.

The conveying channel 3 may also be permanently inclined to some angle other than vertical or horizontal or the apparatus 11 may comprise an inclinable conveying channel 3 capable of being inclined with tipping means to a desired angle other than horizontal plane.

The upright, inclined or inclinable conveying channel 3 allows for the passage of biomass without separate forwarding means as the biomass travels gravitationally from top downwards in a continuous and undisturbed plug flow. The utilization of gravity in the passage of biomass allows the apparatus 11 to have
5 a structure that is simple and more reliable in operation as the passage of biomass in a hot environment does not require separate forwarding means, which are susceptible to malfunctions due to the conditions.

The conveying channel 3 can also be horizontal, whereby the passage of biomass requires conveyor means, for example a conveyor belt.

10 At a top part 3a of the conveying channel 3, the apparatus 11 is provided with supply means 1, 2 for feeding biomass into the conveying channel 3. The biomass is delivered by way of a rotary feeder 1, and a screw conveyor (feed screw) 2 distributes the biomass across the entire breadth of the wide conveying channel 3, after which the biomass starts to flow steadily by the action of
15 gravity towards a bottom part 3b of the conveying channel 3.

Each zone 10a, 10b, 10c, 10d is provided with torrefaction means 5, 6, comprising a heat exchanger (radiator) 5 for transferring thermal energy to a torrefying gas used for torrefaction. The heat transfer medium used in the heat exchanger 5 is e.g. hot oil or high-pressure steam (>60 bar). In addition, the heat
20 transfer means 5, 6 comprise a fan 6 for blowing the torrefying gas through the conveying channel 3 and the biomass essentially in a cross-flow relative to the conveying channel 3 and the biomass flowing direction by way of openings present in the conveying channel 3.

Depending on initial moisture, the blowing direction may change or remain the same, whereby, if necessary, the biomass can be circulated several times
25 through the apparatus 11. The change of blowing direction or the circulation of biomass improves the end product in terms of the consistency of its quality.

The torrefying gas refers to a gas, which is used in torrefaction for the transfer of heat and which comprises for example superheated water vapor or water
30 vapor containing extracts released from a material to be torrefied.

Each fan 6 has capability of supplying the conveying channel 3 with torrefying gas through openings in the wall of the conveying channel at a rate of speed sufficient to develop turbulent currents around biomass particles present in the

conveying channel 3 for maximizing the transfer of energy from the flow simultaneously to each biomass particle. In the event of a laminar flow, there is easily left between the torrefying gas and the surface of biomass particles an insulating boundary zone that decelerates the transfer of energy.

- 5 In each zone 10a, 10b, 10c, 10d, the apparatus 11 has measuring means (not shown), for example at least one temperature sensor, which are adapted to measure temperature of a flowing torrefying gas in the vicinity of the conveying channel 3, having been installed for example on a suction or pressure side of the fans 6. Alternatively, in the event of several temperature sensors, the latter
10 can be installed on suction and pressure sides so as to straddle the conveying channel 3.

- If the zone 10a, 10b, 10c, 10d is provided with several temperature sensors, the latter can be set for example in rows of one or more temperature sensors at various heights (as a network) in the vertical direction of the conveying
15 channel 3.

- The apparatus 11 is further provided with control means (not shown), which are adapted to control the zone-specific torrefaction means 5, 6 of each zone 10a, 10b, 10c, 10d, for example for raising the torrefying gas temperature, for lowering the torrefying gas temperature (cooling), for changing the torrefying
20 gas flowing direction and/or for inertization by means of the torrefying gas, on the basis of measurement data received from the measuring means.

- It is also possible to lower the temperature in a zone-specific manner by adjusting with the zone's heat exchangers 5 and/or with one or more moistening nozzles (not shown) mounted on the pressure side, whose control is effected
25 by using the control means.

The control means make it possible to control one or more zones 10a, 10b, 10c, 10d, or all the zones 10a, 10b, 10c, 10d at a time.

- Torrefied biomass is unloaded from the bottom part 3b of the conveying channel 3 with discharge means 4, comprising a discharge roller assembly (discharge screw) 4 for discharging the torrefied biomass across the entire breadth
30 of the conveying channel 3 and a rotary feeder 9 for unloading the torrefied biomass from the apparatus 11.

The screw conveyor 2, conveying channel 3, heat exchangers 5, fans 6 and discharge roller assembly 4 of the apparatus 11 make up a compact unit, by means of which the drying and/or torrefaction of biomass can be performed efficiently and economically.

- 5 The complete torrefaction plant includes as an essential component a hot dryer, wherein the material is supplied with drying energy through the intermediary of superheated steam. The apparatus 11 can also function as a dryer, since the operating principle of a dryer matches that of the apparatus 11 but with a lower applied temperature. Due to a lower temperature, the biomass does not
10 undergo thermal modification and the process does not require inertization, which is why the rotary feeders 1, 9 are not necessary in regard to operation of the dryer.

- On the other hand, the rotary feeders 1, 9 are needed in torrefaction as the process must take place in inertized conditions in which the temperature sur-
15 passes the ignition temperature of a processed biomass. Inertization is mainly conducted by means of water evaporating from biomass, but also, when necessary, by feeding water or water vapor into the torrefaction apparatus 11 should the water released from biomass be not enough to maintain the oxygen content of the apparatus 11 at a sufficiently low level.

- 20 The apparatus 11 is further provided with an overpressure damper 7, by means of which it is maintained at overpressure and by means of which is conducted a removal of resulting process gases, i.e. water vapor and substances evaporating from biomass. The apparatus 11 is maintained at overpressure in order to prevent the leaks, possibly developed in operation, from
25 causing a fire/explosion hazard which results if oxygen is allowed into the apparatus 11.

Alternatively, the process gases are condensed in the apparatus 11 in a condenser (not shown) included therein, and are conducted to combustion or to an appropriate cleaning process.

- 30 It is possible that drying and torrefaction be conducted in a single apparatus 11 by adjusting the zones 10a, 10b, 10c, 10d individually pursuant to the requirements of drying and torrefaction. The zone-specific adjustment of gas amount may nevertheless lead to imbalance in the apparatus 11.

Indeed, the apparatus 11 can be therefore equipped with a bypass channel 8 with a function of maintaining a gas balance in the apparatus 11.

5 In the event that pre-drying and torrefaction are carried out in one and the same apparatus 11, the pre-drying will be conducted by the heat exchangers 5 in the upper part at a lower temperature and the apparatus 11 has its lower part provided for torrefaction with the heat exchangers 5 generating a higher temperature.

10 In a larger - major industrial scale - the drying phase takes place typically in a first apparatus 11, after which the process can be carried on with a torrefaction phase in a separate second apparatus 11 working on the same operating principle. For more efficient energy consumption, the plant can be further provided with a pre-drying feature, wherein the low temperature residual heat resulting from steam coming out of the apparatus 11 and from thermal energy production can be utilized for thereby improving the plant's energy efficiency.

15 The apparatus 11 is operating continuously, the desired handling process being achieved by regulating the motion speed of biomass and the conditions of various zones 10a, 10b, 10c, 10d.

20 Optionally, the apparatus 11 can be a batch operating system, employing conveyors for filling with biomass which during the course of drying and/or torrefaction is stationary in the conveying channel 3, and the course of the process is controlled by means of the amount and temperature of air circulating in the apparatus 11. The cooling phase is followed by unloading the apparatus 11 with the discharge roller assembly 4.

25 The foregoing principle of the invention can be naturally varied within the scope of protection defined by the claims, regarding for example implementation details as well as fields of use.

Claims

1. A torrefaction apparatus (11), comprising
a conveying channel (3) adapted to pass a material to be torrefied, said
conveying channel comprising openings for enabling torrefaction and being di-
5 vided into at least one zone (10a, 10b, 10c, 10d),
torrefaction means (5, 6) adapted to transfer thermal energy into a torrefying gas used for torrefaction and to introduce the torrefying gas into the conveying channel essentially in a cross-flow by way of its openings,
measuring means adapted to measure temperature of the flowing torrefying gas in the vicinity of the conveying channel, and
10 control means which, jointly with the torrefaction means, enable a zone-specific adjustment of the torrefying gas temperature and flowing direction on the basis of measurement data received from the measuring means.
2. A torrefaction apparatus according to claim 1, wherein the control
15 means are adapted for raising or lowering the torrefying gas temperature, as well as for inertization by means of the torrefying gas, on the basis of measurement data received from the measuring means.
3. A torrefaction apparatus according to any of the preceding claims, wherein the torrefaction means comprise at least one heat exchanger (5) for
20 transferring thermal energy into the torrefying gas and at least one fan (6) for introducing the torrefying gas into the conveying channel.
4. A torrefaction apparatus according to any of the preceding claims, wherein the at least one fan is adapted to introduce the torrefying gas by way of the conveying channel's openings into the conveying channel at a rate of
25 speed which enables its turbulent flow within the interstices of a material to be torrefied.
5. A torrefaction apparatus according to any of the preceding claims, wherein the conveying channel is an upright, inclined or inclinable conveying
channel (3), which is adapted to move gravitationally the material to be torrefied.
30
6. A torrefaction apparatus according to any of the preceding claims, which is further provided with supply means (1, 2), comprising a rotary feeder (1) for supplying the torrefaction apparatus with a material to be torrefied and a screw

conveyor (2) for distributing the material to be torrefied across the entire breadth of the conveying channel.

7. A torrefaction apparatus according to any of the preceding claims, which is further provided with discharge means (4, 9), comprising a discharge roller assembly (4) for discharging the torrefied material across the entire breadth of the conveying channel and a rotary feeder (9) for unloading the torrefied material from the torrefaction apparatus.

8. A torrefaction apparatus according to any of the preceding claims, which is further provided with an overpressure damper (7) used for maintaining the torrefaction apparatus at overpressure and for allowing process gases to escape from the torrefaction apparatus, and with a bypass channel (8) used for maintaining a gas balance in the torrefaction apparatus in case the torrefaction apparatus is also used for drying the material to be torrefied.

9. A torrefaction method, which is adapted to be carried out in a torrefaction apparatus (11) according to any of claims 1-8, said method comprising passing a material to be torrefied in a conveying channel (3), which comprises openings for enabling torrefaction and which is divided into at least one zone (10a, 10b, 10c, 10d),

using torrefaction means (5, 6) to transfer thermal energy into a torrefying gas used for torrefaction, and using the torrefaction means to introduce the torrefying gas into the conveying channel essentially in a cross-flow by way of its openings,

using measuring means for measuring temperature of the flowing torrefying gas in the vicinity of the conveying channel, and

using control means and the torrefaction means for adjusting the temperature and flowing direction of the torrefying gas in a zone-specific manner on the basis of measurement data received from the measuring means.

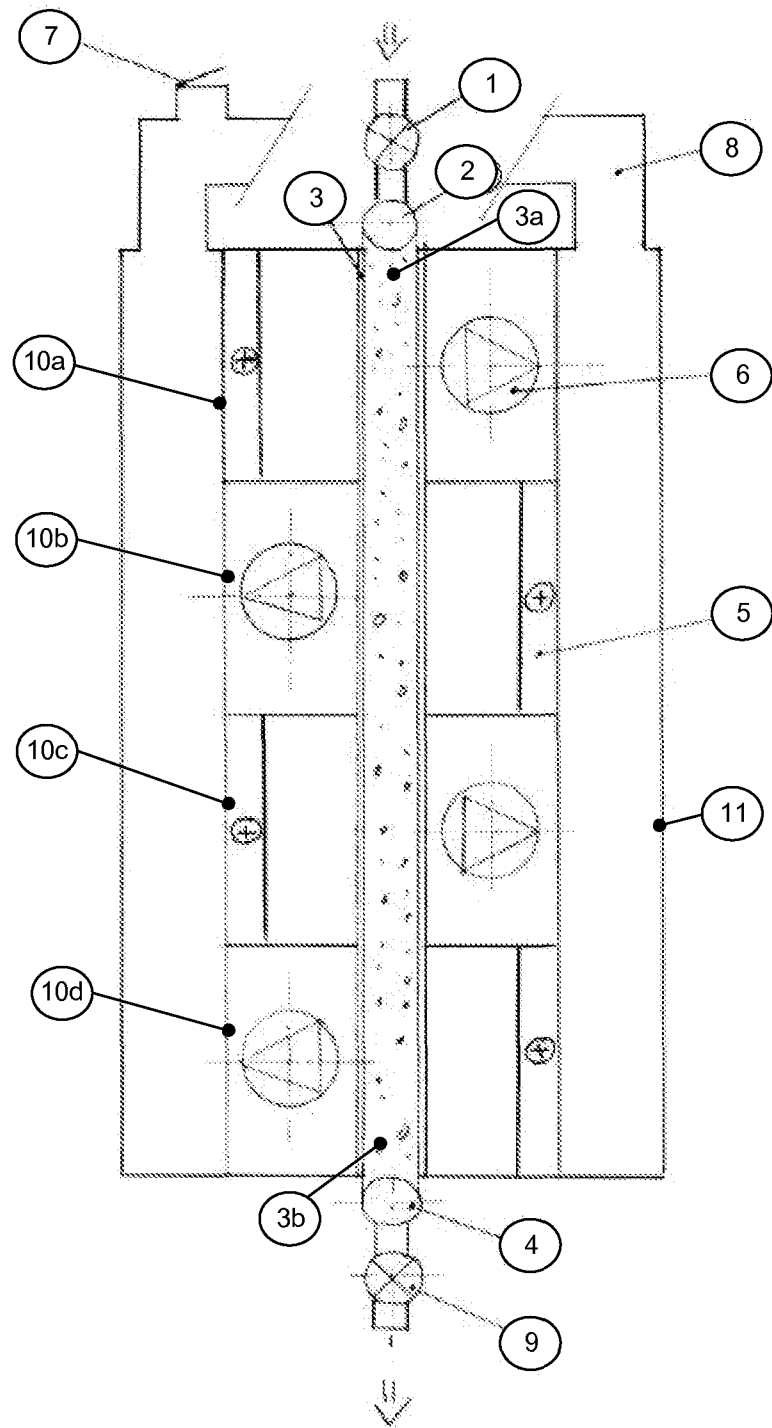


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C10L, C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
FI, SE, NO, DK

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

EPO-Internal, WPI, XPESP, COMPDX, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 3211590 A1 (GREUL ARTUR RICHARD) 13 October 1983 (13.10.1983) abstract [online] EPOQUENET EPODOC; figures 1-4	1-9
A	EP 2189512 A1 (COCKERILL MAINTENANCE ET INGEN [BE]) 26 May 2010 (26.05.2010) abstract	1-9
A	WO 2012158110 A1 (BIOENDEV AB [SE]) 22 November 2012 (22.11.2012) abstract; claims 1-4	1-9

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"P" document published prior to the international filing date but later than the priority date claimed	

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INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
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