



(51) International Patent Classification:

C10L 5/44 (2006.01) *F26B 23/00* (2006.01)
C10L 9/08 (2006.01)

(21) International Application Number:

PCT/SE2012/050531

(22) International Filing Date:

16 May 2012 (16.05.2012)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1150458-6 18 May 2011 (18.05.2011) SE

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(81) Designated States (unless otherwise indicated, for every

kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD,
SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: METHOD AND AN ARRANGEMENT FOR EFFICIENT TORREFACTION OF BIOMASS

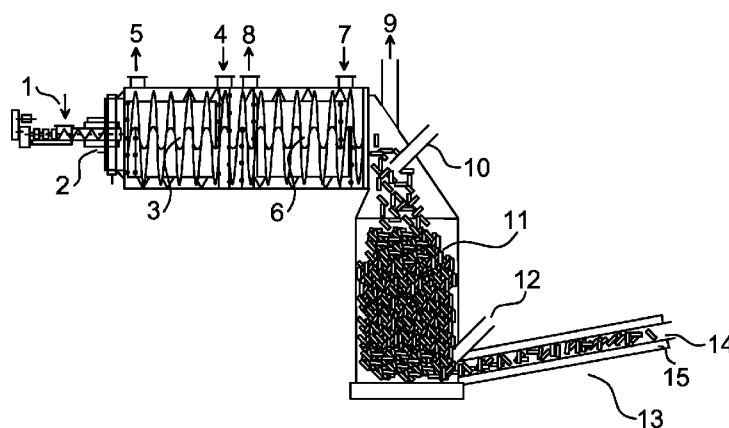


Fig. 1b

(57) **Abstract:** The invention relates to a method and a system for efficient torrefaction of a biomass. Said system comprises a first zone for heating of an optionally pre-dried biomass and an insulated second zone for torrefying the heated biomass. The second zone has an inlet being connected to an outlet of the first zone and means for withdrawing torrefied biomass arranged at the bottom of the second zone, such that the biomass can move downwards through the second zone by means of gravity. Means for heating are arranged at the first zone, but not at the second zone.

METHOD AND AN ARRANGEMENT FOR EFFICIENT TORREFACTION OF BIOMASS

Technical field

The present invention relates to the field of torrefaction of biomass. In particular, it relates to a method and an arrangement for efficient torrefaction of biomass.

5

Background

To be able to compete with and replace fossil fuel energy carriers such as coal, oil and natural gas, lignocellulosic biomass would benefit from some form of pre-treatment method to overcome inherent drawbacks. The pre-treatment method torrefaction has been shown to improve biomass fuel qualities such as energy density, water content and milling, feeding and hydrophobic properties [1-4]. These improvements establish torrefaction as a key process in facilitating an expanding market for biomass raw materials. Torrefaction is a thermal pre-treatment method that normally takes place in a substantially inert (oxygen free) atmosphere at a temperature of about 220-600°C. During the process course a combustible gas comprising different organic compounds is produced from the biomass feedstock in addition to the torrefied biomass.

The process of producing a torrefied material from lignocellulosic biomass can be said to include four stages:

- 1) a drying step, wherein free water retained in the biomass is removed;
- 2) a heating step in which physically bound water is released and the temperature of the material is elevated to the desired torrefaction temperature;
- 25 3) a torrefaction stage, in which the material is actually torrefied and which starts when the material temperature reaches about 220°C -230°C. During this stage, the biomass partly decomposes and gives off different types of volatiles, such as hydroxy acetone, methanol, propanal, short carboxylic acids

etc. In particular, the torrefaction stage is characterized by decomposition of hemicellulose at temperatures from 220°C -230°C, and at higher torrefaction temperatures cellulose and lignin also starts to decompose and give off volatiles; cellulose decomposes at a temperature of 305-375°C and lignin gradually decomposes over a temperature range of 250-500°C;

4) a cooling step to terminate the process and facilitate handling. The torrefaction process is terminated as soon as the material is cooled below 220°C -230°C.

10 Summary of the present disclosure

In torrefaction of industrial scale, a simple, robust and yet energy efficient torrefaction arrangement will provide a major competitive advantage.

Thus the present disclosure provides a new method and a new system for torrefaction of a biomass

15

In one aspect the invention relates to torrefaction of an optionally pre-dried biomass, comprising the steps of:

- a) heating the optionally pre-dried biomass in at least one heating zone such that the temperature of the biomass reaches a torrefaction temperature range; and
- 20 b) torrefying the heated biomass from step a) in a torrefaction zone by maintaining the temperature within the torrefaction temperature range, wherein the heated biomass from step a) is fed to the torrefaction zone at its top and torrefied material is withdrawn from the torrefaction zone at its
- 25 bottom, such that the biomass moves downwards through the torrefaction zone by means of gravity.

In another aspect the invention relates to a system for torrefaction of biomass, comprising:

- 30 a first zone for heating of an optionally pre-dried biomass; and
an insulated second zone for torrefying the heated biomass, said second zone having an inlet being connected to an outlet of the first zone,

means for withdrawing torrefied biomass arranged at the bottom of the second zone, such that the biomass can move downwards through the second zone by means of gravity,

wherein means for heating are arranged at the first zone, but not at the second zone.

Brief description of the figures

Figure 1 shows a system for torrefaction of biomass

Figure 2 shows a typical temperature variation over time in the torrefaction arrangement disclosed in figure 1.

Figure 3 shows a typical temperature variation over time in the torrefaction arrangement disclosed in figure 1.

Definitions

Torrefaction:

A pre-treatment, wherein a biomass, in a virtually inert (oxygen-reduced or oxygen free) atmosphere is heated to a temperature above 220 °C but below 600 °C to produce a torrefied biomass and torrefaction gases comprising combustible gases. Oxygen supplied to a torrefaction reaction in accordance with an embodiment of the present invention, is supplied in such a manner and/or in such an amount that it not, to a substantial degree, reacts with the biomass. Instead, such oxygen reacts with the torrefaction gases. During a torrefaction stage, parts of the biomass, in particular hemicellulose, decompose and give off different types of organic volatiles. In a torrefaction process starting from raw, wet biomass, the actual torrefaction stage is preceded by a drying stage wherein free water retained in the biomass is removed and by a heating stage wherein the biomass is heated to the desired torrefaction temperature.

Heating zone:

A specific region of a compartment in a torrefaction reactor, located upstream of a torrefaction zone in relation to a biomass inlet of a torrefaction reactor, comprising means for specifically regulating the temperature in said specific

region and wherein the temperature of a biomass is increased to a temperature near the desired torrefaction temperature prior to torrefaction.

Torrefaction zone:

- 5 A specific region of a compartment in a torrefaction reactor, located downstream of a heating zone in relation to a biomass inlet of a torrefaction reactor, comprising means for specifically regulating the temperature in said specific region and wherein the temperature of a previously heated biomass is kept virtually constant at the desired torrefaction temperature for a desired
10 torrefaction time wherein a desired torrefaction temperature is in a range between 220 °C to 600 °C.

Drying zone:

- A specific region of a compartment in a torrefaction reactor, located upstream
15 of a heating zone in relation to a biomass inlet of a torrefaction reactor, comprising means for regulating the temperature in said specific region and wherein a biomass is dried to a water content below 10 % prior to heating.

Torrefaction time:

- 20 The time the temperature of the material is kept virtually constant at the torrefaction temperature. The residence time of the material in the torrefaction zone may be referred to as the torrefaction time.

Horizontal:

- 25 The meaning of the term horizontal in the present disclosure is the same as it would be interpreted by the skilled person i.e. a plane perpendicular to a vertical plane and parallel to the plane of the horizon. However in the present disclosure a plane deviating with a small angle (such as 10°) from the horizontal plane is also referred to as horizontal. Thus e.g. the expression “a
30 horizontal heating chamber” also includes heating chambers which deviate with a small angle (such as 10°) from the horizontal plane.

Vertical:

The meaning of the term vertical in the present disclosure is the same as it would be interpreted by the skilled person i.e. a plane perpendicular to a horizontal plane. However in the present disclosure a plane deviating with a small angle (such as 10°) from the vertical plane is also referred to as vertical.

- 5 Thus e.g. the expression “a vertical reactor” also includes reactors which deviate with a small angle (such as 10 °) from the vertical plane.

Detailed description

10 In a first aspect the invention relates to a method for torrefaction of an optionally pre-dried biomass, comprising the steps of:

- a) heating the optionally pre-dried biomass in at least one heating zone such that the temperature of the biomass reaches a torrefaction temperature range; and
 - b) torrefying the heated biomass from step a) in a torrefaction zone
- 15 by maintaining the temperature within the torrefaction temperature range, wherein the heated biomass from step a) is fed to the torrefaction zone at its top and torrefied material is withdrawn from the torrefaction zone at its bottom, such that the biomass moves downwards through the torrefaction zone by means of gravity.

20 This method has several advantages compared to the methods described in the prior art. Since the dried and heated biomass is fed into the torrefaction zone at its top and the torrefied material is withdrawn from the torrefaction zone at its bottom, no moveable parts are needed in the torrefaction zone. Instead, the material moves through the torrefaction zone

25 by means of gravity. This provides for a simple and thus cheap construction. Further, such a construction provides for an energy-efficient torrefaction process: no heating means are needed at the torrefaction zone. It is sufficient that the torrefaction zone is insulated such that the temperature range reached during the heating step is maintained.

30 The residence time of the material in the torrefaction zone is determined by the height (or volume, if cross-section area not constant) of the bed of material in the torrefaction zone and the rate by which the material is withdrawn from the bottom. The withdrawal rate may for example be

controlled by controlling the speed of a transport device, such a transport screw, arranged at the bottom of the torrefaction zone. The height of the bed depends on the initial degree of filling, the withdrawal rate at the bottom and the feeding rate at the top. If the feeding rate at the top is higher than the withdrawal rate at the bottom, the height will increase, and if the withdrawal rate at the bottom is higher than the feeding rate at the top, the height will decrease. The residence time of the material in the torrefaction zone may be controlled in order to control the degree of torrefaction of the material. Thus, the initial degree of filling of the torrefaction zone, the feeding rate to the top of the torrefaction zone and/or the withdrawal rate from the bottom of the torrefaction zone may be controlled to control the degree of torrefaction of the material.

Thus, in one embodiment the torrefied material is withdrawn from the bottom by means of a transport device, such as a transport screw, and the speed of the transport device can for example be controlled in order to control the residence time of the material in the torrefaction zone.

In one embodiment at least one sensor in the torrefaction zone reads the height of the bed in the torrefaction zone. In one embodiment the reading from said sensor is used to control the residence time of the biomass in the torrefaction zone. In one embodiment the reading from the sensor is compared to a reference value and if the reading deviates from the reference value with more than a predetermined error value, the withdrawal rate from the bottom of the torrefaction zone and/or the feeding rate at the top of the torrefaction zone is adjusted.

In one embodiment the torrefaction temperature range is within 220-600 °C, such as 220-500 °C, such as 220-450 °C, such as 220-400 °C, such as 230-600 °C, such as 230-500 °C, such as 230-450 °C, such as 230-400 °C, preferably 240-500 °C, preferably 240-400 °C, preferably 240-350 °C most preferably 270-350 °C.

The temperature is preferably kept relatively constant in the torrefaction zone to facilitate a controlled torrefaction process. Thus, the torrefaction temperature range, which is reached in step a) and maintained in step b), is preferably a range of 50 °C or less. Thus, the torrefaction

temperature range may for example be 300-350 °C or 350-400 °C. More preferably, the temperature range is a range of 40 °C or less, such as 30 °C or less, such as 20 °C or less, such as 10 °C or less.

The heating zone and the torrefaction zone may be separated such
5 that the residence time of the material in the different zones may be controlled separately. For example, the material may be transported through the heating zone by means of a transport device, such as a conveyor belt or a transport screw. Thus, the speed of such a transport device may be controlled to control the residence time of the material in the heating zone. In a preferred
10 embodiment the biomass is transported through the heating zone in a horizontal direction. The control of the residence time of the material in the torrefaction zone is discussed above.

Preferably the torrefaction zone is isolated to such an extent that no external energy has to be provided in the torrefaction zone. The temperature
15 may thus be kept substantially constant in the torrefaction zone due to the isolation and due to the exothermal-heat generated by the biomass during the torrefaction reaction.

The inventors have also discovered that the temperature in the torrefaction zone can be regulated by injection of a controlled amount of air or
20 oxygen into the torrefaction zone. The injected air/oxygen reacts with gases released from the biomass during the torrefaction stage. When the gases partly oxidize, heat is released to the surrounding gas and the material to be torrefied, thereby boosting the temperature without further supply of external heating. The inventors have surprisingly been able to demonstrate that it is
25 possible to keep a controlled temperature in the torrefaction arrangement despite that oxygen is introduced (data not shown). The inventors have even shown that the temperature in the torrefaction zone can be controlled by controlling the amount of injected oxygen (data not shown), which eliminate the need for supplying external heating to the torrefaction zone. The fact that
30 the temperature in the torrefaction arrangement could be kept stable and controlled in the presence of oxygen and without oxidation of the biomass is surprising, especially in light of the torrefaction processes described in the prior art where efforts have been made to ensure that the torrefaction process is performed in an oxygen depleted manner. Therefore, in one embodiment
35 an oxygen-containing gas is supplied to the torrefaction zone.

The present inventors have been able to demonstrate that, compared to supplying the oxygen-containing gas at the bottom of the torrefaction zone, it is easier to control the temperature in the torrefaction zone if the oxygen-containing gas is supplied at the bottom of the torrefaction zone and if
5 torrefaction gases are withdrawn from the torrefaction zone at the top of the torrefaction zone such that gases move upstream through the torrefaction zone, countercurrent to the biomass transport.

Therefore, in a preferred embodiment the oxygen-containing gas is supplied to a first position in the torrefaction zone such that oxygen reacts
10 with components of torrefaction gases under the formation of heat and wherein torrefaction gases are withdrawn from the torrefaction reactor at a second position of the torrefaction reactor and wherein the first position is located downstream of the second position in relation to a biomass transport direction in the torrefaction zone such that the torrefaction gases moves
15 through the torrefaction zone countercurrent to the biomass transport.

In one embodiment the oxygen-containing gas is supplied at the bottom of the torrefaction zone such that oxygen reacts with components of the torrefaction gases under the formation of heat and wherein torrefaction gases are withdrawn from the torrefaction zone at the top of the torrefaction
20 zone such that the torrefaction gases moves through the torrefaction reactor countercurrent to the biomass transport. In one embodiment the oxygen-containing gas is supplied in a position located in the lowest 20 %, preferably lowest 5 %, preferably lowest 1 % of the torrefaction zone and the torrefaction gases are withdrawn from a position corresponding to the highest 20 %
25 preferably highest 5 %, preferably highest 1 % of the torrefaction zone.

In a most preferred embodiment the oxygen-containing gas is supplied to the torrefaction zone and the torrefaction gases are withdrawn from the heating zone such that the torrefaction gases moves through both the
30 torrefaction zone and through the heating zone countercurrent to the biomass transport. In one embodiment the torrefaction gases are withdrawn from a position corresponding to the first 20 % preferably first 5 %, preferably first 1 % of the heating zone. In this sense "first 20 %" means the 20 % closest to the biomass inlet of the heating zone. In one embodiment the oxygen-
35 containing gas is supplied in a position located in the lowest 20 %, preferably lowest 5 %, preferably lowest 1 % of the torrefaction zone. Thereby the heat

generated by the reaction between oxygen and torrefaction gases in the torrefaction zone can be used for drying and heating the biomass in the heating zone. Since the torrefaction gases is drawn countercurrent in relation to the biomass transport, the present inventors have realized that it is possible to inject additional oxygen in the top of the torrefaction zone to boost the temperature in the heating zone without getting a too high temperature in the torrefaction zone. Thus, in one embodiment additional oxygen is added at the top of the torrefaction zone or in a region corresponding to the highest 10 %, preferably highest 5 %, preferably highest 1 % of the torrefaction zone.

10

In an alternative embodiment the oxygen-containing gas is supplied to the torrefaction zone at its top, such that oxygen reacts with components of torrefaction gases formed in the torrefaction zone under the formation of heat and wherein an underpressure is provided at the bottom of the torrefaction zone such that gases move downwards through the torrefaction zone. This embodiment is however less preferred since the present inventors have demonstrated that it is harder keep a stable temperature in the torrefaction zone when the oxygen-containing gas is supplied at the top of the reactor and when the gases are moving concurrently with the biomass within the torrefaction zone.

20

The heat generated by the reaction is distributed throughout the biomass bed in the torrefaction zone. The use of oxygen for boosting the temperature in the torrefaction zone is energy efficient and facilitates efficient control of torrefaction temperature without the need of supplying external energy to the torrefaction zone.

25

In one embodiment, a fraction of hot gases generated by the reaction between oxygen and torrefaction gases in the torrefaction zone is diverted from the top of the torrefaction zone and routed to the heating zone and/or drying zone, to boost the temperature in the heating zone and/or drying zone.

30

In one embodiment the biomass is lignocellulosic biomass, such as a wood material, e.g. wood chips.

Another aspect of the invention relates to a system for torrefaction of biomass, comprising:

35

a first zone for heating of an optionally pre-dried biomass; and an insulated second zone for torrefying the heated biomass, said second zone having an inlet being connected to an outlet of the first zone, means for withdrawing torrefied biomass arranged at the bottom of the second zone, such that the biomass can move downwards through the second zone by means of gravity, wherein means for heating are arranged at the first zone, but not at the second zone.

In one embodiment the first zone is arranged in a heating chamber comprising a screw or belt for transporting the biomass through the first zone.

In another embodiment the heating chamber is horizontal and the screw or belt extends in a horizontal direction for horizontal transport of the biomass. In another embodiment the heating chamber is parallel to the horizontal plane or deviates from the horizontal plane with an angle smaller than 45°, such as smaller than 40°, such as smaller than 35°, such as smaller than 30°, such as smaller than 25°, such as smaller than 20°, such as smaller than 15°.

In one embodiment the insulated second zone is arranged in a vertical reactor. In one embodiment the insulated second zone is arranged in a reactor which is parallel to the vertical plane or deviates from the vertical plane with an angle smaller than 45°, such as smaller than 40° such as smaller than 35° such as smaller than 30°, such as smaller than 25° such as smaller than 20° such as smaller than 15°.

In one embodiment the second zone comprises at least one oxygen inlet for injection of an oxygen-containing gas to the second zone. In one embodiment the oxygen inlet is connected to oxygen supply means for a controlled supply of an oxygen-containing gas to the second zone. In one embodiment the second zone comprises an outlet for torrefaction gases. In one embodiment the outlet for torrefaction gases is located upstream of the oxygen inlet in relation to a biomass transport direction within the second zone. In a preferred embodiment the outlet for torrefaction gases is located in the first zone, preferably at a position corresponding to the first 20 % preferably first 5 %, preferably first 1 % of the first zone, in relation to the

biomass inlet. In one embodiment the system further is comprising a source of the oxygen-containing gas, which source is connected to the oxygen supply means.

5 In one embodiment the oxygen inlet is arranged at the lowest 20 %, preferably lowest 5 %, preferably lowest 1 % of the second zone. In one embodiment the outlet for torrefaction gases is arranged at the highest 20 % preferably highest 5 %, preferably highest 1 % of the second zone.

10 In one embodiment the outlet for torrefaction gases is arranged in the first zone such that torrefaction gases are draw counter current with the biomass transport through both the first and the second zone. Preferably the outlet for torrefaction gases is located in a region corresponding to the first 20 % of the first zone, preferably first 5 %, preferably first 1 % of the first zone.

15 In an alternative embodiment the oxygen inlet is arranged at the top of the second zone and a fan is arranged in connection to the bottom of the second zone such that an underpressure may be provided at the bottom of the second zone. Thus, the gases may be drawn through the second zone. In one embodiment the system comprises a source of the oxygen-containing
20 gas, which source is connected to the oxygen supply means

In one embodiment the second zone comprises at least one sensor for measuring the level of biomass within the second zone. Said measured value could be used to control the residence time of the biomass in the second
25 zone.

Detailed description of exemplary embodiments

Figure 1a shows a system for torrefaction of biomass having a biomass inlet (1) wherein the biomass is introduced in the torrefaction arrangement by
30 means of a feeding screw (2). The biomass is dried in a drying zone (3). Heat is supplied to the drying zone (3) by means of a heating media (e.g. hot gases) through a drying zone heating media inlet (4). The heating media leaves the drying zone through the drying zone heating media outlet (5). Dried biomass is transported from drying zone (3) into a heating zone (6)

where the temperature of the biomass is elevated to the torrefaction temperature range. The heat is supplied to the heating zone (6) by means of a heating media through a heating zone heating media inlet (7). The heating media leaves the heating zone (6) through a heating zone heating media outlet (8). The drying zone (3) and heating zone (6) are both located in a common horizontal reactor and the material transport in the drying zone (3) and heating zone (6) is mediated by a common transport screw which also feeds the material to the top of a vertical reactor comprising the torrefaction zone (11). Torrefied material is withdrawn from the torrefaction zone at its bottom, such that the biomass moves downwards through the torrefaction zone (11) by means of gravity. No external heat is supplied in the torrefaction zone (11) and the torrefaction temperature is monitored by measuring the surface temperature of the biomass using a first IR-thermometer (10) at the top of the torrefaction zone and a second IR-thermometer (12) at the bottom of the torrefaction zone (11). The temperature of the biomass in the torrefaction zone (11) can be adjusted by injection of oxygen-containing gas at the top of the torrefaction zone (11), such that oxygen reacts with components of torrefaction gases formed in the torrefaction zone under the formation of heat. An underpressure is provided at the bottom of the torrefaction zone such that gases move downwards through the torrefaction zone (11). The heat generated by the reaction with the oxygen is thus distributed throughout the biomass bed in the torrefaction zone (11). A cooling zone transport screw (14) moves the torrefied material from the bottom of the torrefaction zone (11) through a cooling zone (13) where the torrefied material is cooled to a temperature below 100 °C by means for cooling (15). Cooling could also be supplied via the transport screw (14). The residence time of the biomass in the torrefaction zone is determined by the speed of the rotation speed of the cooling zone transport screw (14) and by the height of the bed in the torrefaction zone (14). The height of the bed in the torrefaction zone (11) is determined by the rate of material transport into the torrefaction zone, and by the rate at which the material transported out of the torrefaction zone (11). The rate of material transport into the torrefaction zone (11) is determined by the rotation speed of the transport screw in the drying zone (3)

and heating zone (6), and the rate of material transport out of the torrefaction zone is determined by the rotation speed of the cooling zone transport screw (14).

Figure 1b shows the same system for torrefaction as in figure 1 when
5 biomass is present in the system.

Figure 2 and 3 show typical temperature variation over time in the torrefaction arrangement disclosed in figure 1. Despite that no external energy is supplied in the torrefaction zone, the temperature in the torrefaction zone is kept constant. If the temperature would decrease, oxygen can be
10 injected at the top of the torrefaction zone to boost the temperature.

CLAIMS

1. A method for torrefaction of an optionally pre-dried biomass,
5 comprising the steps of:
a) heating the optionally pre-dried biomass in at least one heating
zone such that the temperature of the biomass reaches a torrefaction
temperature range; and
b) torrefying the heated biomass from step a) in a torrefaction zone
10 by maintaining the temperature within the torrefaction temperature range,
wherein the heated biomass from step a) is fed to the torrefaction zone
at its top and torrefied material is withdrawn from the torrefaction zone at its
bottom, such that the biomass moves downwards through the torrefaction
zone by means of gravity, and wherein an oxygen-containing gas is supplied
15 to the torrefaction zone.

2. Method according to claim 1 wherein the oxygen-containing gas is
supplied to the torrefaction zone such that oxygen reacts with components of
torrefaction gases under the formation of heat and wherein torrefaction gases
20 are withdrawn from the heating zone such that the torrefaction gases moves
through the torrefaction zone and through the heating zone countercurrent to
the biomass transport.

3 A method according to claim 1-2, wherein the torrefied material is
25 withdrawn from the bottom by means of a transport device, such as a
transport screw.

4 A method according to claim 3, wherein the speed of the transport
device is controlled to control of the residence time of the material in the
30 torrefaction zone.

5 A method according to anyone of claims 1-4, wherein the torrefaction
temperature range is within 220 °C to 600 °C, such as 220-500 °C, such as

220-450 °C, such as 220-400 °C, such as 230-600 °C, such as 230-500 °C, such as 230-450 °C, such as 230-400 °C, preferably 240-500 °C, preferably 240-400 °C, preferably 240-350 °C, most preferably 270-350 °C.

5 6 A method according to any one of the preceding claims, wherein the biomass is transported through the heating zone in a horizontal direction.

7 A system for torrefaction of biomass, comprising:
a first zone for heating of an optionally pre-dried biomass; and
10 an insulated second zone for torrefying the heated biomass, said second zone having an inlet being connected to an outlet of the first zone, means for withdrawing torrefied biomass arranged at the bottom of the second zone, such that the biomass can move downwards through the second zone by means of gravity,
15 wherein means for heating are arranged at the first zone, but not at the second zone.

8 The system according to claim 7, wherein the first zone is arranged in a heating chamber comprising a screw or a belt for transporting the
20 biomass through the first zone.

9 The system according to claim 8, wherein the heating chamber is horizontal and the screw or belt extends in a horizontal direction for horizontal transport of the biomass.

25

10 The system according to anyone of claims 7-9, wherein the insulated second zone is arranged in a vertical reactor.

11 The system according to anyone of claims 7-10, comprising at least
30 one oxygen inlet for injection of an oxygen-containing gas to the second zone and at least one outlet for torrefaction gases and wherein the outlet for torrefaction gases is located upstream of the oxygen inlet in relation to a biomass transport direction within the second zone

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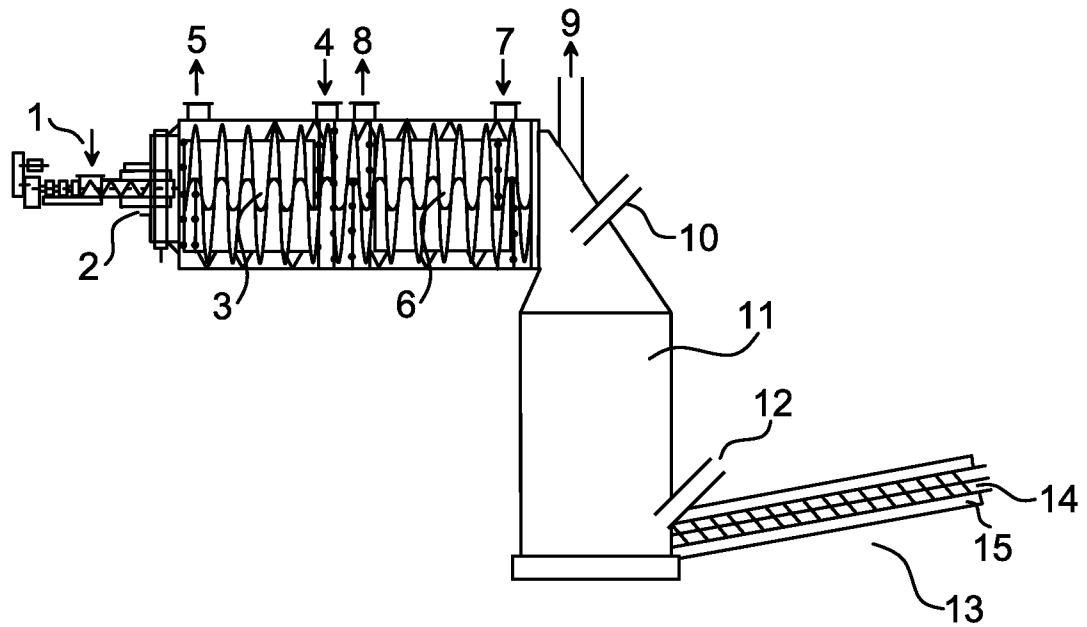


Fig. 1a

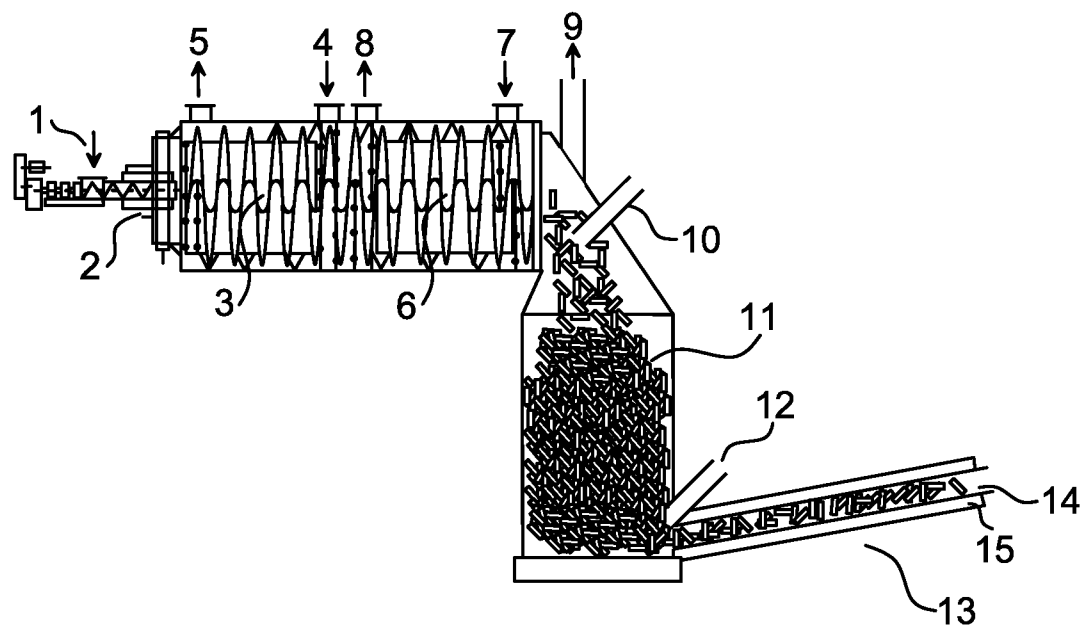


Fig. 1b

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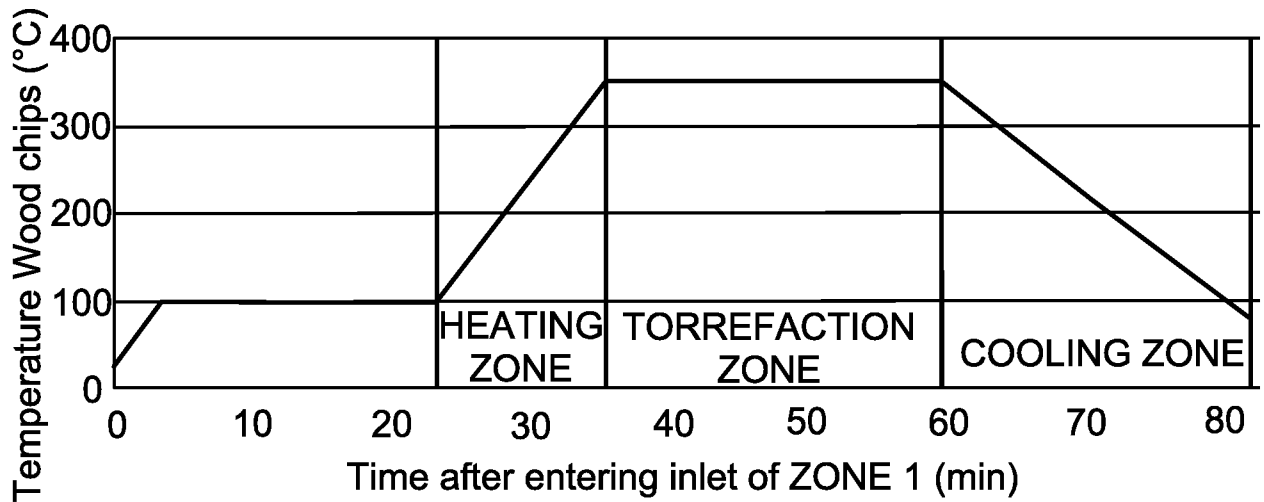


Fig. 2

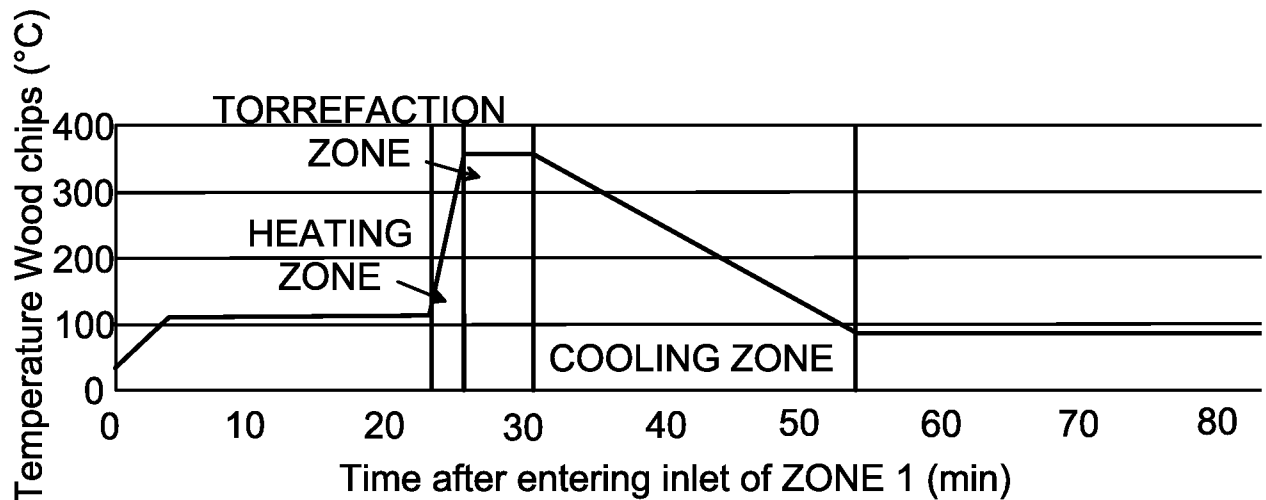


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2012/050531

A. CLASSIFICATION OF SUBJECT MATTER

IPC: 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, F26B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007078199 A1 (STICHTING ENERGIE ET AL), 12 July 2007 (2007-07-12); abstract; page 15, line 26 - page 16, line 30; page 6, line 12 - page 6, line 19; page 8, line 32 - page 9, line 4; figure 5 --	1-6
A	US 20100242351 A1 (CAUSER THOMAS P), 30 September 2010 (2010-09-30); paragraphs [0016]-[0020]; claim 1 --	1-11
A	WO 2010130988 A1 (UNIV ASTON ET AL), 18 November 2010 (2010-11-18); abstract; figure 4 --	1-11



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Date of the actual completion of the international search

28-08-2012

Date of mailing of the international search report

29-08-2012

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2448531 A (COAL PRODUCTS LTD), 22 October 2008 (2008-10-22); page 5, line 21 - page 5, line 29 -- -----	1-11

Continuation of: second sheet

International Patent Classification (IPC)

C10L 5/44 (2006.01)

C10L 9/08 (2006.01)

F26B 23/00 (2006.01)

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International application No.

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