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(54) **IMPROVED PROCESS FOR PRETREATING BIOMASS**

(57) The present invention relates to an improved process and device for pretreating biomass in which a steam/gas mixture is withdrawn from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit for stabilizing the temperature of the process.

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Description

Field of the invention

[0001] The invention generally relates to a process for treating biomass. In particular, the invention relates to a process and a device for treating biomass, wherein the temperature stability of the prehydrolysis treatment of the biomass is improved.

Background art

[0002] When treating biomass it is known in the art to firstly pretreat the biomass in a prehydrolysis reactor in which the hemicellulose is dissolved from the biomass under pressure and heat in the presence of steam and optionally in the presence of a catalyst and/or suitable chemical substance. A typical temperature interval for the pretreatment reaction is between 120 °C and 225 °C whereby a pressure of up to 25 bar is obtained. The typical residence time of the biomass in the prehydrolysis reactor is in the range of from 2 min to 60 min, such as from 2 min to 30 min. These parameters depend on the desired extent of pretreatment in the reactor as well as on the presence of additional catalysts or chemical substances.

[0003] Usually the pretreatment process is conducted continuously, whereby the biomass is continuously fed into the prehydrolysis reactor by means of a feeding device and the pretreated biomass is continuously discharged from the prehydrolysis reactor by means of a discharger. Suitable ways of discharging the pretreated biomass are e.g. by means of steam explosion, i.e. a rapid decrease of pressure creating a flashing of the steam and destructuration of the biomass; by means of dilution discharge, wherein the pretreated biomass is diluted in the discharger so that the dilution water decreases the temperature and avoids a rapid pressure drop, so that no steam flashing occurs; or other discharging methods, such as through a refiner, by pumping, sluice valve etc. Steam is added to the prehydrolysis reactor through one or more steam inlets, preferably several steam inlets, which are distributed near the biomass inlet and optionally over the length of the reactor.

[0004] During dilution discharge the dilution water in the discharger creates a seal lock so that the steam cannot escape from the prehydrolysis reactor through the discharger, so that steam consumption is largely decreased. As a consequence the circulation of the steam from the biomass feeding point to the biomass discharge is greatly diminished so that the steam does not circulate through the biomass bed in the prehydrolysis reactor. Additionally, gas formed during the pretreatment is not evacuated from the prehydrolysis reactor and thus forms a buffer which decreases the heating of the biomass.

[0005] These problems result in a temperature decrease during the pretreatment operation and thereby a reduced operability and efficiency of the pretreatment process.

Summary of the invention

[0006] The present invention resides in the finding that the temperature decrease during the pretreatment process can be avoided resulting in an even temperature profile over the length of the prehydrolysis reactor by withdrawing a small amount of a steam/gas mixture via at least one outlet in the area at the upper end of the prehydrolysis reactor unit.

[0007] By withdrawing a steam/gas mixture from the pretreatment reactor unit the steam circulation in the prehydrolysis reactor unit can be increased so that the steam is circulated through the biomass bed in the reactor more efficiently. Additionally, a more even temperature profile over the length of the prehydrolysis reactor can be obtained. Consequently, the pretreatment reaction of the biomass in the reactor is more efficient so that the residence time in the pretreament reactor can be reduced.

[0008] The present invention relates to a process for treating biomass comprising the steps of:

(A) Feeding biomass into a pressurized prehydrolysis reactor unit by means of a feeding system;
(B) Feeding steam into the pressurized prehydrolysis reactor unit;
(C) Thermally treating the biomass in the pressurized prehydrolysis reactor unit by contacting the biomass with steam;
(D) Diluting the thermally treated biomass;
(E) Discharging the diluted thermally treated biomass from the pressurized prehydrolysis reactor unit;

characterized in that
a steam/gas mixture is withdrawn from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit.

[0009] Further, the present invention relates to a device for treating biomass comprising

- a pressurized prehydrolysis reactor unit for thermally treating biomass;
- a feeding system for feeding biomass into the upper part of the pressurized prehydrolysis reactor unit;
- at least one inlet for steam at the upper part of the pressurized prehydrolysis reactor unit;
- two or more means for measuring temperature situated at different parts of the pressurized prehydrolysis reactor unit;
- a discharging unit for discharging the thermally treated biomass from the pressurized prehydrolysis reactor unit;
- at least one inlet for water into the discharging unit;
- at least one outlet for a steam/gas mixture situated at the upper part of the pressurized prehydrolysis reactor unit.

[0010] Still further, the present invention relates to the use of withdrawal of a steam/gas mixture from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit for stabilizing the temperature of a process for treating biomass comprising the steps of:

(A) Feeding biomass into a pressurized prehydrolysis reactor unit by means of a feeding system;
(B) Feeding steam into the pressurized prehydrolysis reactor unit;
(C) Thermally treating the biomass in the pressurized prehydrolysis reactor unit by contacting the biomass with steam;
(D) Diluting the thermally treated biomass;
(E) Discharging the diluted thermally treated biomass from the pressurized prehydrolysis reactor unit.

Definitions

[0011] Biomass is any source of plant material suitable for converting into pulp and paper material, cellulose-based construction material or biofuel. Suitable sources of biomass are lignocellulosic biomass such as virgin biomass, waste biomass and energy crops. Virgin biomass includes all naturally occurring terrestrial plants such as trees, bushes and grass. Waste biomass is produced as a low-value byproduct of various industrial sectors such as agriculture, e.g. selected from corn stover, sugarcane bagasse, straw etc., and forestry, e.g. selected from saw mill and paper mill discards. Energy crops are crops with high yield of lignocellulosic biomass produced to serve as a raw material for production of second generation (2G) biofuel. Examples include switch grass (*Panicum virgatum*) and elephant grass.

[0012] A prehydrolysis reactor unit is a unit including several entities suitable for pretreating biomass. In the pretreatment process the biomass is rendered accessible for the downstream hydrolysis process steps. Additionally, hemicellulose is dissolved from the biomass under pressure and heat in the presence of steam and optionally in the presence of a catalyst and/or suitable chemical substance. A prehydrolysis reactor unit usually comprises a feeding system for feeding biomass into to the prehydrolysis reactor unit, a charging section, situated at the upper part of the prehydrolysis reactor unit, through which the biomass is charged into the prehydrolysis reactor by means of the feeding system, a prehydrolysis reactor in which the biomass is pretreated under pressure and heat in the presence of steam and optionally in the presence of a catalyst and/or suitable chemical substance, and a discharging unit through which the pretreated biomass is discharged from the prehydrolysis reactor by means of dilution discharge.

[0013] The upper part of the prehydrolysis reactor unit denotes the part of the prehydrolysis reactor unit that is the highest part of the prehydrolysis reactor unit in the sense of the farthest from the floor in vertical direction. Usually, the upper part of the prehydrolyis reactor makes up the upper 1/5th of the prehydrolysis reactor unit. For a vertical prehydrolysis reactor unit the upper part is situated in the area of the charging section through which the biomass is fed into the prehydrolysis reactor. For a horizontal prehydrolysis reactor unit the upper part is situated in the vertically highest part of the prehydrolysis reactor over the whole length of the prehydrolysis reactor.

Detailed description

Process

[0014] The present invention relates to a process for treating biomass comprising the steps of:

(A) Feeding biomass into a pressurized prehydrolysis reactor unit by means of a feeding system;
(B) Feeding steam into the pressurized prehydrolysis reactor unit;
(C) Thermally treating the biomass in the pressurized prehydrolysis reactor unit by contacting the biomass with steam;
(D) Diluting the thermally treated biomass;
(E) Discharging the diluted thermally treated biomass from the pressurized prehydrolysis reactor unit;

characterized in that
a steam/gas mixture is withdrawn from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit.

[0015] Before feeding the biomass into the pressurized prehydrolysis reactor the biomass can be pretreated by cutting and/or washing.
The biomass can additionally be pretreated by dilute acid hydrolysis by contacting the biomass with a dilute solution containing an external acidic catalyst, reinforced autohydrolysis by contacting the biomass with a dilute solution containing a recirculated acidic catalyst or autohydrolysis by contacting the biomass with water. These pretreatment measures are well known in the art.

[0016] In one embodiment the biomass fed into the pressurized prehydrolysis reactor unit is preferably a solid dry material.

[0017] In another embodiment the biomass fed into the pressurized prehydrolysis reactor unit is preferably an aqueous slurry of biomass.

[0018] The biomass is fed into the pressurized prehydrolysis reactor unit by means of a feeding system.

[0019] It is preferred that the biomass is continuously fed into the pressurized prehydrolysis reactor unit.

[0020] The feeding system is preferably situated at the upper part of the pressurized prehydrolysis reactor.

[0021] Preferably the feeding system comprises means for actively conveying the biomass into the pressurized prehydrolysis reactor unit. Such means is/are

preferably selected from a plug screw feeder, a force feed screw feeder, a rotary valve or combinations thereof. Suitable means for actively conveying the biomass into the pressurized prehydrolysis reactor unit are known in the art.

[0022] The biomass is preferably fed into the pressurized prehydrolysis reactor unit through a charging section. The charging section is usually situated at the upper part of the pressurized prehydrolysis reactor unit.

In a vertical pressurized prehydrolysis reactor unit the charging section usually has the form of a vertical pipe which connects the feeding system with the upper part of the vertically arranged pressurized prehydrolysis reactor.

In a horizontal pressurized prehydrolysis reactor unit the charging section usually has the form of a horizontally arranged pipe which bends downwardly in vertical direction which connects the feeding system with the upper part of the horizontally arranged pressurized prehydrolysis reactor.

[0023] Through the charging section the biomass is vertically fed into the upper part of the pressurized prehydrolysis reactor.

[0024] The pressurized prehydrolysis reactor unit can comprise one or more reactors such as one or two reactors.

[0025] In one embodiment the pressurized prehydrolysis reactor unit comprises more than one reactor such as two reactors. If the pressurized prehydrolysis reactor unit comprises more than one reactor, e.g. an impregnation reactor and a prehydrolysis reactor, the reactors are usually arranged in series. For example, biomass can be fed into an impregnation reactor and then be impregnated in the impregnation reactor. Afterwards, the biomass can be discharged from the impregnation reactor and fed to the subsequent respectively downstream prehydrolysis reactor. The pressurized prehydrolysis reactor unit can also comprise two or more prehydrolysis reactors arranged in series and operating at same or different temperature and pressure.

[0026] In another embodiment the pressurized prehydrolysis reactor unit comprises only one reactor which suitably is a prehydrolysis reactor.

[0027] In the pressurized prehydrolysis reactor unit the biomass is thermally treated, preferably in the presence of water under pressure, more preferably by heating with steam, to produce a thermally treated biomass. In particular, the biomass can be exposed to steam in the pressurized prehydrolysis reactor unit, wherein the steam is fed into the prehydrolysis reactor unit in addition to the biomass. By exposing the biomass to steam, the biomass is pressurized in the prehydrolysis reactor unit, and by heating the pressurized biomass, the thermally treated biomass is produced.

[0028] Steam is preferably fed into the pressurized prehydrolysis reactor unit through at least one inlet, wherein at least one inlet is situated at the upper part of the reactor of the pressurized prehydrolysis reactor unit, preferably near the charging section and at least one optional additional inlet(s) is/are situated at different parts along the reactor of the pressurized prehydrolysis reactor unit.

[0029] By feeding steam through more than one inlet into the pressurized prehydrolysis reactor unit distributed along the reactor of the pressurized prehydrolysis reactor unit it can be ensured that the steam is more evenly distributed over the reactor and an improved steam circulation can be obtained. Steam can also be used for supporting and facilitating the discharge of the pretreated biomass from the pressurized prehydrolysis reactor unit.

[0030] For further improving the steam circulation in the pressurized prehydrolysis reactor unit a steam/gas mixture is withdrawn from at least one outlet situated at the upper art of the pressurized prehydrolysis reactor unit.

Thereby, the withdrawn steam usually originates from the steam fed into the pressurized prehydrolysis reactor as discussed above or below.

The withdrawn gas usually originates from gas formed during the pretreatment reaction in the prehydrolysis reactor unit.

[0031] In one embodiment the steam/gas mixture is withdrawn from the pressurized prehydrolysis reactor unit through a single outlet. Said outlet is usually situated at or near the highest point of the pressurized prehydrolysis reactor unit.

In a vertical pressurized prehydrolysis reactor unit the single steam/gas mixture outlet is preferably situated at or near the highest point of the vertically arranged reactor of the pressurized prehydrolysis reactor unit.

In a horizontal pressurized prehydrolysis reactor unit the single steam/gas mixture outlet is preferably situated at or near the charging section, suitably in the upper part of the horizontally arranged pipe between the feeding system and the horizontally arranged reactor. Said horizontally arranged pipe of the charging section usually is the highest point in a horizontal pressurized prehydrolysis reactor unit.

[0032] In another embodiment the steam/gas mixture is withdrawn from the pressurized prehydrolysis reactor unit through more than one outlet. Thereby, the first outlet is preferably situated at or near the highest point of the pressurized prehydrolysis reactor unit as described above for the single outlet.

The other additional steam/gas mixture outlet(s) is/are suitably situated further downstream along the reactor of the pressurized prehydrolysis reactor unit.

[0033] In a vertical pressurized prehydrolysis reactor unit the other additional steam/gas mixture outlet(s) is/are suitably situated downwards from the first steam/gas mixture outlet along the vertically arranged reactor of the pressurized prehydrolysis reactor unit.

In a horizontal pressurized prehydrolysis reactor unit the other additional steam/gas mixture outlet(s) is/are suitably situated downstream from the first steam/gas mixture outlet at the upper part of the horizontally arranged reactor of the pressurized prehydrolysis reactor unit. Suit-

ably in this embodiment the steam/gas mixture is withdrawn from the pressurized prehydrolysis reactor unit through two, three or four outlets.

[0034] Preferably, the two or more means for measuring temperature are situated at different parts of the pressurized prehydrolysis reactor unit and the temperature in the pressurized prehydrolysis reactor unit is continuously monitored.

Suitable means for measuring the temperature in the pressurized prehydrolysis reactor unit are temperature sensors as known in the art.

[0035] Preferably two means for measuring temperature are situated at the reactor the pressurized prehydrolysis reactor unit at or near the area in which the biomass is fed, such as at or near the charging section, and at or near the area in which the biomass is discharged, such as at or near the discharging unit.

Optional additional means for measuring temperature can be evenly distributed over the length of the pressurized prehydrolysis reactor unit.

[0036] Suitably, the biomass is thermally treated by heating to a temperature of from 120 °C to 225 °C, preferably of from 150 °C to 210 °C and most preferably of from 180 °C to 200 °C.

Said temperature range can suitably be controlled by monitoring the temperature with the two or more means for measuring temperature.

[0037] The pressure in the reactor of the pressurized prehydrolysis reactor unit is preferably up to 25 bar, more preferably from 5 bar to 20 bar, most preferably from 7.5 bar to 15 bar.

[0038] In one operational embodiment of the process of the invention the steam/gas mixture is withdrawn from the one or more outlet(s) situated in an area at the upper part of the pressurized prehydrolysis reactor unit periodically when a temperature drop during the operation below a predetermined temperature range is monitored.

Usually the predetermined temperature range is from 0.1 to 10 °C, preferably from 0.5 to 5.0 °C, or even more preferably from 0.5 to 1.5 °C.

The temperature range is predetermined before start of the process. As soon as the temperature determined at one of the means for measuring temperature drops below the predetermined temperature range the steam/gas mixture is withdrawn either automatically or manually, preferably automatically.

[0039] In another operational embodiment of the process of the invention the steam/gas mixture is withdrawn from the at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit continuously during operation.

In said embodiment the temperature can still be continuously monitored.

In said embodiment, the steam/gas mixture may additionally be withdrawn from the one or more outlet(s) situated in an area at the upper part of the pressurized prehydrolysis reactor unit periodically when a temperature drop during the operation below a predetermined temperature range is monitored.

The additional periodic withdrawal can be obtained either by periodically withdrawing a higher amount of steam/gas mixture for the at least one steam/gas mixture outlet(s) or by additionally periodically withdrawing the steam/gas mixture through a steam/gas mixture outlet which was not used for continuous steam/gas mixture withdrawal.

Usually the predetermined temperature range is from 0.1 to 10°C, preferably from 0.5 to 5.0°C, or even more preferably from 0.5 to 1.5 °C.

[0040] The temperature range is predetermined before start of the process. As soon as the temperature determined at one of the means for measuring temperature drops below the predetermined temperature range the steam/gas mixture is withdrawn either automatically or manually, preferably automatically.

[0041] The diluted thermally treated biomass is preferably discharged from the pressurized prehydrolysis reactor unit through a discharging unit. In particular, the diluted thermally treated biomass is preferably discharged from the pressurized prehydrolysis reactor unit through an orifice and/or a blow valve of the pressurized prehydrolysis reactor unit.

[0042] Before discharge, the thermally treated biomass is preferably diluted by contact with water. Thereby, the water is preferably fed into the discharging unit of the pressurized prehydrolysis reactor unit.

[0043] By diluting the thermally treated biomass the temperature of the thermally treated biomass is preferably reduced before discharge to a temperature range of from 50 °C to 140 °C, preferably from 65 °C to 130 °C and most preferably from 80 °C to 120 °C.

[0044] Preferably, the diluted thermally treated biomass is discharged from the pressurized prehydrolysis reactor unit by dilution discharge. Dilution discharge means that the dilution water decreases the temperature and avoids a rapid pressure drop, so that no steam flashing occurs.

In particular, the biomass can have a temperature below 100 °C during discharging and no flashing occurs during discharging. Alternatively, the biomass can have a temperature above 100 °C during discharging and a flashing occurs. However, this flashing occurs without a steam explosion occurring during discharging.

Dilution discharge is a technique well known in the art of biomass pretreatment.

[0045] Preferably, the diluted thermally treated biomass is continuously discharged from the pressurized prehydrolysis unit.

[0046] The residence time of the biomass in the pressurized prehydrolysis reactor unit is usually in the range of from 2 min to 60 min, such as from 2 min to 30 min.

[0047] The thermally treated biomass discharged from the pressurized prehydrolysis reactor unit preferably has a temperature of from 50 °C to 150 °C, preferably from 65 °C to 130 °C and most preferably from 80 °C to 120 °C.

[0048] Suitably, the thermally treated biomass discharged from the pressurized prehydrolysis reactor unit

is further processed in a hydrolysis reaction as known in the art.

[0049] It has surprisingly be found that the prehydrolysis process of the invention can be run more efficiently when a steam/gas mixture is withdrawn from the pressurized prehydrolysis reactor unit during operation. Presumably, the withdrawal of the steam/gas mixture ensures improved steam circulation through the pressurized prehydrolysis reactor unit which reduces or even avoids a temperature drop during operation. As a consequence the pretreatment reaction of the biomass can be improved and the residence time of the pretreated biomass in the pressurized prehydrolysis reactor unit can be reduced.

Device

[0050] The present invention also relates to a device for treating biomass comprising

- a pressurized prehydrolysis reactor unit for thermally treating biomass;
- a feeding system for feeding biomass into the upper part of the pressurized prehydrolysis reactor unit;
- at least one inlet for steam at the upper part of the pressurized prehydrolysis reactor unit;
- two or more means for measuring temperature situated at different parts of the pressurized prehydrolysis reactor unit;
- a discharging unit for discharging the thermally treated biomass from the pressurized prehydrolysis reactor unit;
- at least one inlet for water into the discharging unit;
- at least one outlet for a steam/gas mixture situated at the upper part of the pressurized prehydrolysis reactor unit.

[0051] The pressurized prehydrolysis reactor unit preferably comprises a feeding system for feeding biomass into to the prehydrolysis reactor unit, a charging section, situated at the upper part of the prehydrolysis reactor unit, through which the biomass is charged into the prehydrolysis reactor by means of the feeding system, a prehydrolysis reactor in which the biomass is pretreated under pressure and heat in the presence of steam and optionally in the presence of a catalyst and/or suitable chemical substance, and a discharging unit through which the pretreated biomass is discharged from the prehydrolysis reactor by means of dilution discharge.

[0052] The feeding system is preferably situated at the upper part of the pressurized prehydrolysis reactor.

[0053] Preferably, the feeding system comprises means for actively conveying the biomass into the pressurized prehydrolysis reactor unit. Such means are preferably selected from a plug screw feeder, a force feed screw feeder, a rotary valve or combinations thereof. Suitable means for actively conveying the biomass into the pressurized prehydrolysis reactor unit are known in the art.

[0054] In one embodiment the pressurized prehydrolysis reactor unit comprises more than one reactor such as two reactors. If the pressurized prehydrolysis reactor unit comprises more than one reactor, e.g. an impregnation reactor and a prehydrolysis reactor, the reactors are usually arranged in series. For example, biomass can be fed into an impregnation reactor and then be impregnated in the impregnation reactor. Afterwards, the biomass can be discharged from the impregnation reactor and fed to the subsequent respectively downstream prehydrolysis reactor. The pressurized prehydrolysis reactor unit can also comprise two or more prehydrolysis reactors arranged in series and operating at same or different temperature and pressure.

[0055] In another embodiment the pressurized prehydrolysis reactor unit comprises only one reactor which suitably is a prehydrolysis reactor.

[0056] Preferably, the pressurized prehydrolysis reactor unit is a vertical pressurized prehydrolysis reactor unit or a horizontal pressurized prehydrolysis reactor unit.

[0057] The pressurized prehydrolysis reactor unit preferably comprises a charging section. The charging section is usually situated at the upper part of the pressurized prehydrolysis reactor unit.

In a vertical pressurized prehydrolysis reactor unit the charging section usually has the form of a vertical pipe which connects the feeding system with the upper part of the vertically arranged pressurized prehydrolysis reactor.

In a horizontal pressurized prehydrolysis reactor unit the charging section usually has the form of a horizontally arranged pipe which bends downwardly in vertical direction which connects the feeding system with the upper part of the horizontally arranged pressurized prehydrolysis reactor.

[0058] The at least one inlet for steam is preferably situated at the upper part of the reactor of the pressurized prehydrolysis reactor unit preferably near the charging section and at least one optional additional inlet(s) is/are situated at different parts along the reactor of the pressurized prehydrolysis reactor unit.

[0059] The device according to the invention further comprises at least one outlet for a steam/gas mixture situated at the upper part of the pressurized prehydrolysis reactor unit.

[0060] In one embodiment the device comprises a single outlet for a steam/gas mixture. Said outlet is usually situated at or near the highest point of the pressurized prehydrolysis reactor unit.

In a vertical pressurized prehydrolysis reactor unit the single steam/gas mixture outlet is preferably situated at or near the highest point of the vertically arranged reactor of the pressurized prehydrolysis reactor unit.

In a horizontal pressurized prehydrolysis reactor unit the single steam/gas mixture outlet is preferably situated at or near the charging section, suitably in the upper part of the horizontally arranged pipe between the feeding

system and the horizontally arranged reactor. Said horizontally arranged pipe of the charging section usually is the highest point in a horizontal pressurized prehydrolysis reactor unit.

[0061] In another embodiment the device comprises more than one outlet. Thereby, the first outlet is preferably situated at or near the highest point of the pressurized prehydrolysis reactor unit as described above for the single outlet.

The other additional steam/gas mixture outlet(s) is/are suitably situated further downstream along the reactor of the pressurized prehydrolysis reactor unit.

[0062] In a vertical pressurized prehydrolysis reactor unit the other additional steam/gas mixture outlet(s) is/are suitably situated downwards from the first steam/gas mixture outlet along the vertically arranged reactor of the pressurized prehydrolysis reactor unit.

In a horizontal pressurized prehydrolysis reactor unit the other additional steam/gas mixture outlet(s) is/are suitably situated downstream from the first steam/gas mixture outlet at the upper part of the horizontally arranged reactor of the pressurized prehydrolysis reactor unit. Suitably in this embodiment the device comprises two, three or four outlets for the steam/gas mixture.

[0063] Preferably, the two or more means for measuring temperature are situated at different parts of the pressurized prehydrolysis reactor unit.

Suitable means for measuring the temperature in the pressurized prehydrolysis reactor unit are temperature sensors as known in the art.

[0064] Preferably two means for measuring temperature are situated at the reactor the pressurized prehydrolysis reactor unit at or near the area in which the biomass is fed, such as at or near the charging section, and at or near the area where the biomass is discharged, such as at or near the discharging unit.

Optional additional means for measuring temperature can be evenly distributed over the length of the pressurized prehydrolysis reactor unit.

[0065] The device further comprises a discharging unit.

The discharging unit comprises at least one inlet for water into the discharging unit. Suitably the discharging unit comprises one inlet for water into the discharging unit.

Further, the discharging unit comprises an orifice and/or a blow valve for discharging the diluted thermally treated biomass.

[0066] Preferably, the device as described above and below is suitable for the process according to the invention as described above or below. All features and embodiments as disclosed for the process also apply for the device.

Use

[0067] The present invention further relates to the use of withdrawal of a steam/gas mixture from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit for stabilizing the temperature of a process for treating biomass comprising the steps of:

(A) Feeding biomass into a pressurized prehydrolysis reactor unit by means of a feeding system;
(B) Feeding steam into the pressurized prehydrolysis reactor unit;
(C) Thermally treating the biomass in the pressurized prehydrolysis reactor unit by contacting the biomass with steam;
(D) Diluting the thermally treated biomass;
(E) Discharging the diluted thermally treated biomass from the pressurized prehydrolysis reactor unit.

Brief description of the drawing

[0068]

Figure 1 shows a vertical pressurized prehydrolysis reactor unit according to the present invention.
Figure 2 shows a horizontal pressurized prehydrolysis reactor unit according to the present invention.

Detailed description of the drawing

Reference numbers

[0069]

1a	vertical pressurized prehydrolysis reactor unit
1b	horizontal pressurized prehydrolysis reactor unit
2	feeding inlet for biomass
3	inlet for steam
4	discharging unit for biomass
5	outlet for a steam/gas mixture
6	means for measuring temperature
7	charging section

[0070] Figure 1 shows a vertical pressurized prehydrolysis reactor unit (1a) into which biomass is fed through a feeding inlet (2) into the charging section (7) situated at the upper part of the vertical pressurized prehydrolysis reactor unit (1a). The biomass is fed into the vertical pressurized prehydrolysis reactor unit (1a) by means of a feeding system (not shown), which can be selected from a plug screw feeder, a force feed screw feeder, a rotary valve or combinations thereof.

The charging section (7) usually has the form of a vertical pipe which connects the feeding system with the upper part of the vertical pressurized prehydrolysis reactor unit (1a). Through the inlet for steam (3) steam is introduced into the upper part of the vertical pressurized prehydrolysis reactor unit (1a). In the embodiment shown in Figure 1 the steam inlet (3) is situated in the charging section (7). The steam (3) can also be situated near the charging section (7). Steam can also be introduced through op-

tional additional steam inlet(s), which can be situated at different parts along the reactor of the vertical pressurized prehydrolysis reactor unit (1a).

By means of steam the biomass is thermally treated in the vertical pressurized prehydrolysis reactor unit (1a). The temperature is thereby usually in the range of from 120 °C to 220 °C, preferably of from 150 °C to 210 °C and most preferably of from 180 °C to 200 °C. The pressure is usually up to 25 bar, preferably of from 5 bar to 20 bar and most preferably of from 7.5 bar to 15 bar.

Two or more means for measuring temperature (6) are situated at the reactor of the vertical pressurized prehydrolysis reactor unit (1a) by which the temperature is continuously monitored.

A steam/gas mixture is withdrawn from the vertical pressurized prehydrolysis reactor unit (1a) from at least one outlet for a steam/gas mixture (5), which is situated at the upper part of the pressurized prehydrolysis reactor unit (1a). The embodiment shown in Figure 1 the outlet for a steam/gas mixture (5) is situated at the upper part of the charging section (7).

The steam/gas mixture can be withdrawn periodically or continuously.

In periodical operational mode the steam/gas mixture is withdrawn when during operation the temperature drops below a predetermined temperature range usually of from 0.1 to 10 °C, preferably from 0.5 to 5.0 °C and most preferably from 0.5 to 1.5 °C. When the temperature drops below said predetermined temperature range a valve of the outlet for a steam/gas mixture either a signal is given which indicates that the valve of the outlet for a steam/gas mixture (5) needs to be opened manually or the valve of the outlet for a steam/gas mixture (5) is opened automatically.

In continuous operational mode the steam/gas mixture is continuously withdrawn during operation. Additionally, the steam/gas mixture may be periodically withdrawn either through an additional outlet for a steam/gas mixture (not shown) in another area at the upper part of the vertical pressurized prehydrolysis reactor unit (1a) or by further opening the valve of the outlet of a steam/gas mixture (5) so that a higher amount of the steam/gas mixture is periodically withdrawn. A periodic withdrawal of the steam/gas mixture during continuous operational mode is usually conduced when a temperature drop below a predetermined temperature range usually of from 0.1 to 10 °C, preferably from 0.5 to 5.0 °C and most preferably from 0.5 to 1.5 °C is monitored. The steam/gas mixture can then be withdrawn either manually or automatically as described above.

[0071] Water is fed into the vertical pressurized prehydrolysis reactor unit (1a) for diluting the thermally treated biomass (not shown). By diluting the thermally treated biomass the temperature of the thermally treated biomass is usually reduced before discharge to a temperature range of from 50 °C to 140 °C, preferably from 65 °C to 130 °C and most preferably from 80 °C to 120 °C. The diluted thermally treated biomass is then discharged through the discharging unit (4). The biomass can be discharged by dilution discharge usually at a temperature of below 100°C and no flashing.

The biomass can also be discharged at a temperature above 100°C and flashing without steam explosion.

The residence time of the biomass in the vertical pressurized prehydrolysis reactor unit (1a) is usually in the range of rom 2 min to 60 min, such as from 2 min to 30 min.

[0072] Figure 2 shows a horizontal pressurized prehydrolysis reactor unit (1b) into which biomass is fed through a feeding inlet (2) into the charging section (7) situated at the upper part of the horizontal pressurized prehydrolysis reactor unit (1b). The biomass is fed into the horizontal pressurized prehydrolysis reactor unit (1b) by means of a feeding system (not shown), which can be selected from a plug screw feeder, a force feed screw feeder, a rotary valve or combinations thereof.

The charging section (7) usually has the form of a horizontally arranged pipe which bends downwardly in vertical direction which connects the feeding system with the upper part of the horizontal pressurized prehydrolysis reactor unit (1b).

Through the inlet for steam (3) steam is introduced into the upper part of the horizontal pressurized prehydrolysis reactor unit (1b). In the embodiment shown in Figure 1 the steam inlet (3) is situated in the charging section (7). The steam (3) can also be situated near the charging section (7). Steam can also be introduced through optional additional steam inlet(s), which can be situated at different parts along the reactor of the horizontal pressurized prehydrolysis reactor unit (1b).

[0073] By means of steam the biomass is thermally treated in the horizontal pressurized prehydrolysis reactor unit (1b). The temperature is thereby usually in the range of from 120 °C to 220 °C, preferably of from 150 °C to 210 °C and most preferably of from 180 °C to 200 °C. The pressure is usually up to 25 bar, preferably of from 5 bar to 20 bar and most preferably of from 7.5 bar to 15 bar.

Two or more means for measuring temperature (6) are situated at the reactor of the horizontal pressurized prehydrolysis reactor unit (1b) by which the temperature is continuously monitored.

A steam/gas mixture is withdrawn from the horizontal pressurized prehydrolysis reactor unit (1b) from at least one outlet for a steam/gas mixture (5), which is situated at the upper part of the horizontal pressurized prehydrolysis reactor unit (1b). The embodiment shown in Figure 1 the outlet for a steam/gas mixture (5) is situated at the upper part of the charging section (7). The steam/gas mixture can be withdrawn periodically or continuously.

In periodical operational mode the steam/gas mixture is withdrawn when during operation the temperature drops below a predetermined temperature range usually of from 0.1 to 10 °C, preferably from 0.5 to 5.0 °C and most preferably from 0.5 to 1.5 °C. When the temperature drops below said predetermined temperature range a valve of the outlet for a steam/gas mixture either a signal

is given which indicates that the valve of the outlet for a steam/gas mixture (5) needs to be opened manually or the valve of the outlet for a steam/gas mixture (5) is opened automatically.

In continuous operational mode the steam/gas mixture is continuously withdrawn during operation. Additionally, the steam/gas mixture may be periodically withdrawn either through an additional outlet for a steam/gas mixture (not shown) in another area at the upper part of the horizontal pressurized prehydrolysis reactor unit (1b) or by further opening the valve of the outlet of a steam/gas mixture (5) so that a higher amount of the steam/gas mixture is periodically withdrawn. A periodic withdrawal of the steam/gas mixture during continuous operational mode is usually conduced when a temperature drop below a predetermined temperature range usually of from 0.1 to 10 °C, preferably from 0.5 to 5.0 °C and most preferably from 0.5 to 1.5 °C is monitored. The steam/gas mixture can then be withdrawn either manually or automatically as described above.

Water is fed into the horizontal pressurized prehydrolysis reactor unit (1b) for diluting the thermally treated biomass (not shown). By diluting the thermally treated biomass the temperature of the thermally treated biomass is usually reduced before discharge to a temperature range of from 50 °C to 140 °C, preferably from 65 °C to 130 °C and most preferably from 80 °C to 120 °C.

The diluted thermally treated biomass is then discharged through the discharging unit (4). The biomass can be discharged by dilution discharge usually at a temperature of below 100°C and no flashing.

The biomass can also be discharged at a temperature above 100°C and flashing without steam explosion.

The residence time of the biomass in the vertical pressurized prehydrolysis reactor unit (1a) is usually in the range of rom 2 min to 60 min, such as from 2 min to 30 min.

Claims

1. A process for treating biomass comprising the steps of:

(A) Feeding biomass into a pressurized prehydrolysis reactor unit by means of a feeding system;
(B) Feeding steam into the pressurized prehydrolysis reactor unit;
(C) Thermally treating the biomass in the pressurized prehydrolysis reactor unit by contacting the biomass with steam;
(D) Diluting the thermally treated biomass;
(E) Discharging the diluted thermally treated biomass from the pressurized prehydrolysis reactor unit;

characterized in that
a steam/gas mixture is withdrawn from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit.

2. The process according to claim 1, wherein the biomass is continuously fed into the pressurized prehydrolysis reactor unit and the diluted thermally treated biomass is continuously discharged from the pressurized prehydrolysis reactor unit.

3. The process according to claim 1 or 2, wherein the feeding system is situated at the upper part of the pressurized prehydrolysis reactor unit and is selected from a plug screw feeder, a force feed screw feeder, a rotary valve, or combinations thereof.

4. The process according to any one of the preceding claims, wherein steam is fed into the pressurized prehydrolysis reactor unit through at least one inlet, wherein at least one inlet is situated at the upper part of the reactor of the pressurized prehydrolysis reactor unit preferably near the charging section and at least one optional additional inlet(s) is/are situated at different parts along the reactor of the pressurized prehydrolysis reactor unit.

5. The process according to any one of the preceding claims, wherein two or more means for measuring temperature are situated at different parts of the pressurized prehydrolysis reactor unit and the temperature in the pressurized prehydrolysis reactor unit is continuously monitored.

6. The process according to any one of the preceding claims, wherein a steam/gas mixture is withdrawn from the at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit periodically when a temperature drop during the operation below a predetermined temperature range is monitored.

7. The process according to any one of claims 1 to 5, wherein a steam/gas mixture is withdrawn from the at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit continuously during operation.

8. The process according to any one of the preceding claims, wherein the biomass is thermally treated by heating to a temperature of from 120 °C to 225 °C.

9. The process according to any one of the preceding claims, wherein the diluted thermally treated biomass is discharged from the pressurized prehydrolysis reactor unit by dilution discharge.

10. The process according to any one of the preceding claims, wherein the diluted thermally treated biomass is discharged from the pressurized prehydrol-

ysis reactor unit is discharged through a discharging unit.

11. The process according to any one of the preceding claims, wherein the thermally treated biomass is diluted by contact with water.

12. The process according to claim 9 wherein the water is fed into the discharging unit of the pressurized prehydrolysis reactor unit.

13. A device for treating biomass comprising

- a pressurized prehydrolysis reactor unit (1a/b) for thermally treating biomass;
- a feeding system for feeding biomass into the upper part of the pressurized prehydrolysis reactor unit (1a/b);
- at least one inlet for steam (3) at the upper part of the pressurized prehydrolysis reactor unit (1a/b);
- two or more means for measuring temperature (6) situated at different parts of the pressurized prehydrolysis reactor unit;
- a discharging unit (4) for discharging the thermally treated biomass from the pressurized prehydrolysis reactor unit;
- at least one inlet for water into the discharging unit;
- at least one outlet for a steam/gas mixture (5) situated at the upper part of the pressurized prehydrolysis reactor unit.

14. The device according to claim 13 wherein the pressurized prehydrolysis reactor unit is a vertical pressurized prehydrolysis reactor unit (1a) or a horizontal pressurized prehydrolysis reactor unit (1b).

15. The use of withdrawal of a steam/gas mixture from at least one outlet situated in an area at the upper part of the pressurized prehydrolysis reactor unit for stabilizing the temperature of a process for treating biomass comprising the steps of:

(A) Feeding biomass into a pressurized prehydrolysis reactor unit by means of a feeding system;
(B) Feeding steam into the pressurized prehydrolysis reactor unit;
(C) Thermally treating the biomass in the pressurized prehydrolysis reactor unit by contacting the biomass with steam;
(D) Diluting the thermally treated biomass;
(E) Discharging the diluted thermally treated biomass from the pressurized prehydrolysis reactor unit.

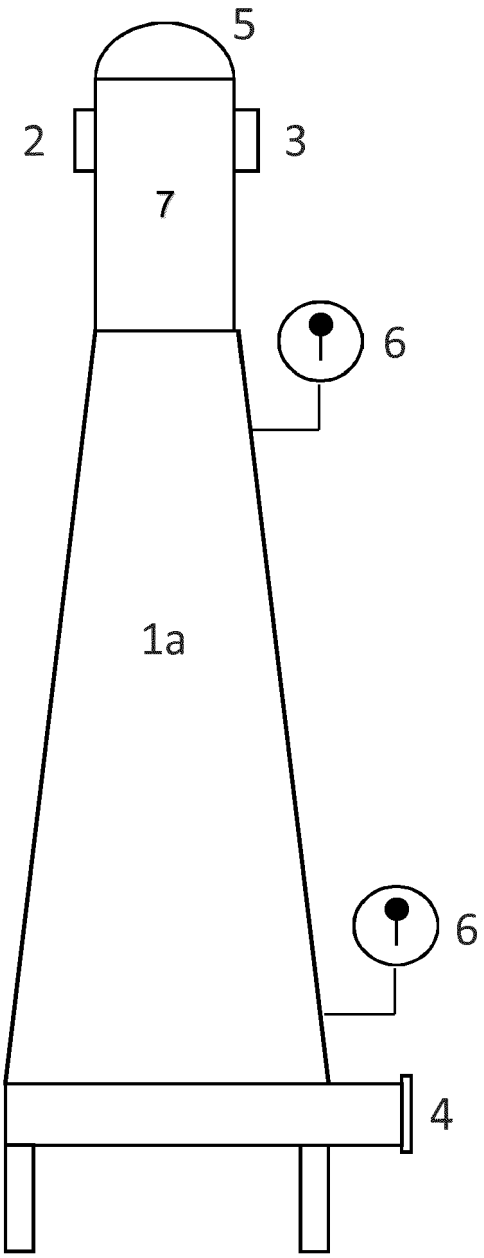

Fig 1

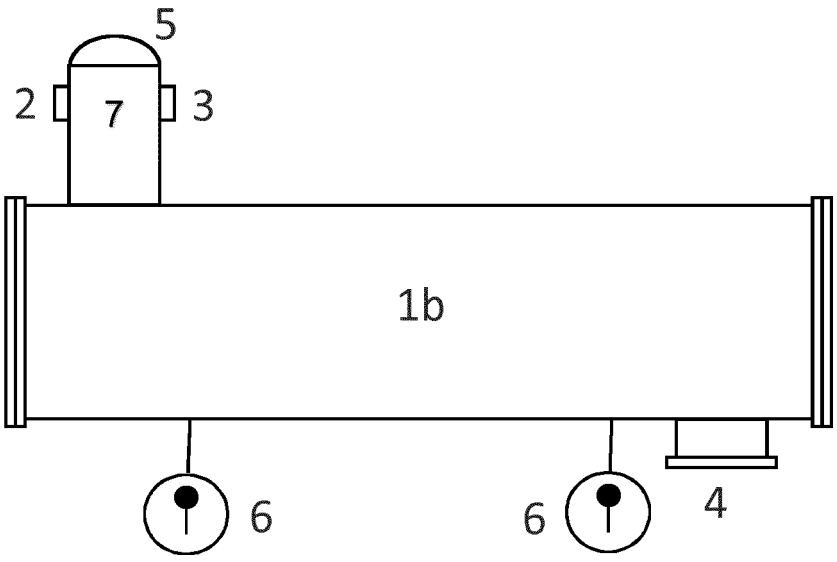

Fig 2

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EUROPEAN SEARCH REPORT

Application Number
EP 18 21 0775

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2017/100907 A1 (IOGEN CORP [CA]) 22 June 2017 (2017-06-22) * paragraphs [0069], [0076], [0159]; figure 1 *	1-15	INV. D21C1/02 D21C7/00 D21C7/10
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TECHNICAL FIELDS SEARCHED (IPC)
D21C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	6 March 2019	Ponsaud, Philippe

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82