

A THERMAL PRE-TREATMENT REACTOR AND PROCESS

Field of the Invention

The invention relates to the thermal pre-treatment of materials for the purpose of combustion, drying and/or gasification. One such application includes torrefaction, with the invention particularly directed to a reactor and process for such pre-treatment, including torrefaction.

Background

An underlying issue with thermal pre-treatment reactors is the manner in which large volumes of material can be processed efficiently, while optimising energy requirements.

Biomass is a natural product that is difficult to heat up and contains small amounts of water that need to be dried out before temperature can reach torrefaction temperature. Biomass, because of low heat transfer characteristics, is difficult to heat homogeneously and has high friction, and so, is difficult to move and to distribute over the volume of the reactor.

The moisture content, in particular, leads to the material having high cohesion and so a high capacity to resist shear forces applied during movement of the material. Unless the material can be efficiently turned over, moisture will be retained. However, the process of turning over a large volume of cohesive material requires overcoming the shear strength of the material, with cohesion between the particles of the material preventing it from flowing.

Existing systems differ in terms of moving the material and application of heat for the removal of moisture. In particular, how the heat is transferred to the biomass and how the biomass flows through the reactor is fundamental to an efficient process.

Regarding movement, existing systems rely on either continuous or batch processes. The application of heat is typically hot gas (combustion gas or other oxygen free gas) to heat up

the product and keep the temperature at torrefaction temperature. Some reactors use a vessel with double heated jacket and have rotating mixers to distribute the heat. For product transport, the material is either transported entrained by gas flow, but mostly the product is moved by conveyors or rotating mixers.

- 5 For the rotating conveyors, in some cases these may use a process of moving material radially on multi-platform reactors, and passing the material either through a central aperture, or at a circumferential gap at the peripheral edge of the platform. In either case, the material tends to create piles of the material at the point of deposition as the material stacks upon itself. The material then needs to be radially shifted again. Given that moisture removal is critical to the process, these piles must then be worked to spread the material for better moisture removal. This further spreading is a redundant process that lengthens residence time and leads to over-processing of the material, as well as unnecessary energy output through redundant movement of the material. Further still, the application of heat to dry the material is most efficient when there is a high surface area. If the material is piled, there is less surface area to apply the heat, and so inherently less efficient. Such systems are inefficient; they have low capacity and high capital expenditure requirements. Further, they tend not to produce consistent quality.

Summary of Invention

20

In a first aspect, the invention provides a reactor for thermal pre-treatment of a material, the reactor comprising: a housing; said housing encompassing a plurality of vertically aligned platforms; each platform having an opening through which material is arranged to pass to a lower platform, the opening being an elongate aperture through the platform and positioned

radially from a central core; each platform further including a rotational scraper, said rotational scraper arranged to rotate about a central core; wherein the rotational scraper is arranged to move material received from an upper platform across a surface of the platform to the elongate radial opening, such that the material drops through the opening onto the lower platform.

In a second aspect, the invention provides a process for thermally pre-treating of a material, the process comprising the steps of: introducing a volume of material to a platform in a reactor; rotationally moving the material about a central core of the platform using a rotational scraper; passing the material through an opening in the platform, the opening being an elongate aperture through the platform and positioned radially from the central core, and so; receiving the material onto a lower platform.

The invention therefore provides a system of firstly creating a uniform spread of material, that is then deposited to the next sub-reactor in the same uniformly spread material. Piling of the material is avoided, and so moisture retention avoided.

Brief Description of Drawings

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention. Other arrangements of the invention are possible, and consequently the particularity of the

accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

Figure 1 is an elevation view of a thermal pre-treatment reactor according one embodiment of
5 the present invention;

Figure 2 is an elevation view of a rotor mechanism for use with a thermal pre-treatment reactor according a further embodiment of the present invention;

Figure 3 is a plan view of a rotating scraper for use with a thermal pre-treatment reactor according a further embodiment of the present invention;

10 Figure 4 is a plan view of a sub-reactor according a further embodiment of the present invention, and;

Figure 5 is a plan view of a static scraper for use with a thermal pre-treatment reactor according a further embodiment of the present invention.

15 **Detailed Description**

The invention seeks to optimise the continuous process of applying a thermal pre-treatment to a material having a moisture content. The invention may be directed to equipment that acts as a heat exchanger for hot and cold processes on solid products where long residence time and conditioning of the enclosed atmosphere is required.

20 In the following description, torrefaction as a specific thermal pre-treatment process will be described. This is not to be interpreted as a limitation of the system and method defined by the invention, but to demonstrate an example of how the invention may be applied.

For a torrefaction application, the biomass may undergo a torrefaction reaction for which three conditions need to be fulfilled:

- Temperature: 210 to 280 degrees Celsius
- Absence of oxygen
- Residence time typical 15 to 30 min.

Torrefaction reaction releases off-gas with high concentrations of tars, which tend to build up on cold spots in the reactor. This gas needs to be evacuated separately from the torrefied biomass output, as it must be treated thermally or chemically before emitting to the environment. The torrefied product when leaving the reactor is hot and 100 % dry, so with any exposure to air it will burn. To avoid this, cooling of the product is mandatory before encountering air.

As shown in Figures 1 to 5, the reactor 5 includes two parts, being a bottom plate 15 and a removable cylindrical hood 10. The plate 15 and hood 10 are connected, by the weight of the hood, to each other with a circular seal 45. In case of an explosion inside the reactor 5, the hood 10 is arranged lift sufficiently to break the circular seal 45 and release the pressure safely over the circumference of the seal area. Within the reactor 5 are a plurality of platforms 65, each having openings rotationally spaced about 345° from each other, possibly in the range $\pm 5^\circ$ to 15° . In alternative embodiments, the tolerance range of $\pm 5^\circ$ to 15° may be the variation of the rotational sweep between platforms. Each platform includes a rotating scraper 57, with the rotating scraper having radially projecting arms 60. The scraper arms are relatively flexible, such that there is sufficient pliability to scrape the material as it spreads, in a similar manner to a spatula. The scraper arms 60 may therefore be coated steel, and may be shaped to as to provide a sharp edge arranged to scrape the platform surface to collect the

material, but stiff enough to prevent the arm 60 yielding under the cohesive mass of the material.

The material, such as biomass, enters the reactor 5 from an opening 55 on the top of the hood 10, and dropping down on a top platform 33. The top platform 33 includes a rotating scraper 57, in combination with the static scraper 30. The scrapers function by the rotating scraper 57 pushing the material against the helically shaped static scraper. This allows the material to spread circumferentially about the top platform 33, providing an even spread of the material over the surface of the top platform 33. As the platform is heated, the product will start to heat up and dry out through a conductive heat transfer process. The circumferential spreading of the material may also assist in drying through a convective heat transfer process.

Modulation of the platform temperature, that is, the ability to apply a different temperature for different platforms, can provide a process in which the thermal conditions are changed over the residence time of the reaction.

The heat applied will depend upon a range of factors, including but not limited to

- i) The type of thermal pre-treatment;
- ii) The necessary residence for the material, which may also be a function of the number of platforms 35 within the reactor 5;
- iii) Ambient temperature, both internally and externally;
- iv) The type and moisture content of material.

The heat may be applied through a range of different means, including embedded electrical heating elements within the platforms or flowing a heating medium through conduits within

the platforms. The heating medium may need to be capable of applying temperatures greater than 250°C, and so steam or synthetic thermal oil may be a preferred option.

After being rotated about 345°, possibly in the range $\pm 5^\circ$ to 15° , on the hot surface of the platform, the material will drop through the opening 70 to the platform 65 below. One rotation may take between 45 to 90 seconds, with this speed is variable and defines the residence time of the product in the reactor. Rotation of the rotational scraper 57 is achieved by a rotary motor 20 and shaft 25, with the shaft being connected to each rotational scraper 57. The rotary motor and shaft may include gearing so as to control the rotational speed of the rotational scrapers 57 such that scrapers on one level may rotate faster or slower than scrapers in another. For instance, it may be beneficial to increase residence time of the material on the top platform 33. To this end, the rotating scraper 57 on the top platform 33 may rotate slower than on other levels. The relative rotational speed of the various scrapers may be selective such that an operator may adjust the relative rotational speeds subject the material type, moisture content or energy requirements. Control over the parameters in removing moisture may be any one or a combination of:

- i) The rotational sweep of about 345°, possibly in the range $\pm 5^\circ$ to 15° of the material on a respective platform. Being a physical parameter, this will tend to be fixed, but may vary between the platforms;
- ii) The rotational speed of the rotatable scraper, which may vary between platforms, and may be selectively variable for each platform;
- iii) The heat applied through the platform, may also be selectively varied, and/or maybe varied between platforms.

As the product will cascade down from top platform 33 to the last platform 43, the total residence time, by way of example, will be the time of one rotation multiplied by the number of platforms, in the embodiment where all the rotational scrapers have the same rotational speed.

The opening 47 of the last platform 43 is located above the outlet 50 of the bottom plate 15, from where the torrefied product is conveyed out for further processing which is not part of the invention.

As during the process, vapour/steam and torrefaction gas is released/evacuated by the material between the platforms, this gas will flow radially through the space defined by the platforms as the gas separates from the material. It is then collected adjacent to the wall of the hood 10, further flowing down along the wall of the hood 10 and evacuated through the outlet 50 in the bottom plate 15. Separation of gas and product occurs on each platform 65 by following separate trajectories; hence, the outgoing torrefied solid product is not contaminated with tars.

In continuous operation, the reactor is arranged to be filled with off-gas if pressure is kept positive (500-1000 Pa), which prevents air entering the reactor 5 and so creating the anaerobic conditions for the torrefaction.

Claims

1. A reactor for thermal pre-treatment of a material, the reactor comprising:
 - a housing;
 - 5 said housing encompassing a plurality of vertically aligned platforms;
 - each platform having an opening through which material is arranged to pass to a lower platform, the opening being an elongate aperture through the platform and positioned radially from a central core;
 - each platform further including a rotational scraper, said rotational scraper arranged to
 - 10 rotate about a central core;
 - wherein the rotational scraper is arranged to move material received from an upper platform across a surface of the platform to the elongate radial opening, such that the material drops through the opening onto the lower platform.
- 15 2. The reactor according to claim 1, wherein the orientation of the openings of adjacent platforms is such that an opening in a platform beneath is rotationally offset by an offset angle from the opening in an above platform.
3. The reactor according to claim 2, wherein the rotational scrapers are arranged to move
- 20 the material received from an above platform through the offset angle before pushing said material into the respective opening, to be received by a platform beneath.

4. The reactor according to any one of claims 1 to 3, further including a static scraper, said static scraper being helical and arranged to spread the material across the surface of the platform as the rotational scraper pushes material into contact with the static scraper.

5

5. The reactor according to any one of claims 1 to 4, wherein said platform surface is heated.

10

6. The reactor according to any one of claims 1 to 5, wherein the housing comprises a bottom plate and a cylindrically shaped hood.

7. The reactor according to any one of claims 1 to 5, wherein said thermal pre-treatment includes torrefaction.

15

8. A process for thermally pre-treating of a material, the process comprising the steps of:
introducing a volume of material to a platform in a reactor;

rotationally moving the material about a central core of the platform using a rotational scraper;

passing the material through an opening in the platform, the opening being an

20

elongate aperture through the platform and positioned radially from the central core, and so;

receiving the material onto a lower platform.

9. The process according to claim 8, further including the steps, after the receiving step, of:

repeating the rotationally moving and passing steps for a plurality of platforms, and
5 then;

passing a treated product through an opening in a bottom platform.

10. The process according to claim 8 or 9, further including the step of heating the material using heaters within the platforms.

10

11. The process according to any one of claims 8 to 10, further including the steps of:

in each platform, passing gas separated from the material radially through a space defined by the platform;

flowing said gas toward an outlet in a bottom plate of said reactor, and;

15 evacuating said gas from the reactor through said outlet.