

APPARATUS FOR CONDUCTING A HYDROTHERMAL CARBONISATION REACTION

The present invention relates to apparatus for conducting a hydrothermal carbonisation reaction, comprising a reaction tank, which is connected with a steam generator to receive hot steam and with a mixing tank by way of a feed pipe to receive biomass and which is connected with a buffer tank to drain off a slurry that forms in the reaction tank from hot steam and biomass.

Apparatus of that kind is already previously known from DE 10 2011 001 108 Al. There, a hydrothermal carbonisation reaction takes place in a reaction tank which is charged from a mixing tank or preheating tank. The mixing tank is connected with the reaction tank by way of a solids pump, which conveys the biomass, after a pre-treatment, into the reaction tank at a lower pressure and a lower temperature by comparison with the reaction conditions in the reactor. Such a mixing tank is designed for the purpose of preparing more or less one batch and then being completely emptied into the reactor.

The actual carbonisation reaction then takes place in the reaction tank under a pressure of about 25 bar and at temperatures from 210° C to 230° C. In this regard, firstly the structures of the biomass are split up in order to split the cellulose of the biomass into glucose within the scope of hydrolysis. The actual carbonisation takes place thereafter. In that case, thorough mixing of the biomass takes place, as does feed of hot steam in order to increase the proportion of water in the mixture and to form a slurry in which the carbonisation reaction can take place as effectively as possible. Finally, within the scope of the final condensation the initially water-soluble carbon components combine to form larger molecules.

After the reaction, the earlier embodiment of the method provides a buffer tank into which the slurry, which has reacted completely, is transferred from the reaction tank. There, the slurry is once again slowly cooled at a lower pressure level.

Ultimately, the method provides for conversion of biomass into the energy source of biocoal. In order to operate as effectively as possible, as much energy as possible should be saved during the process and in addition it is important to optimise the capacity utilisation of the system in order to also work as effectively as possible in this

regard.

Against this background, it is an object of the present invention to further improve the energy balance and to structure the method more effectively.

This is achieved by apparatus for conducting a hydrothermal carbonisation reaction in accordance with the features of claim 1. Further useful embodiments of such apparatus can be inferred from the appendant subclaims.

As a solution for this problem the invention provides in place of a simple mixing tank a so-called pulper which is able to store and prepare a complete day's supply of biomass, more or less permanently, and can thus fill a reaction tank regularly. For this purpose, the biomass is already heated and thoroughly mixed in the pulper and, preferably, hot steam is also already admixed here so that the slurry already occurs in the pulper and therefore can be pumped into the reaction tank very easily and quickly. This reduces the downtimes that were previously required for transport of the biomass into the reaction tank by a solids pump.

Above all, however, the use of a first heat exchanger, which is integrated in the pulper, is particularly advantageous. This heat exchanger forms a heat circuit together with a second heat exchanger, which is integrated in the buffer tank and absorbs heat thereat from the fully reacted slurry drained from the reactor. The heat absorbed in the buffer tank is transported to the pulper by way of the heat circuit and absorbed by the biomass therein. The heat medium, which cools down again as a result, is conducted back to the second heat exchanger in the buffer tank and there cools the slurry again, which transfers its heat to the heat carrier.

A heat circuit thereby results in which the cooling slurry transfers its heat to the biomass, which is to be heated up, and thereby continuously keeps energy in the system, once it has been fed into the system. Furthermore, in order to additionally be able to intervene from the outside at least one further heat exchanger can be provided in the heat circuit, by way of which heat can be fed into or withdrawn from the heat circuit in targeted manner.

Such heat exchangers can be realised in different ways. One possibility consists of

enclosing the respective tank by a double-walled outer sheath. The cavity thus created between the two outer walls can then be subject to throughflow by the heat carrier medium and either receive heat from the inner one of the two walls or deliver heat thereto depending on the place of use. If the pulper additionally has a stirring mechanism, it can be useful to guide the heat carrier in a countercurrent to the flow in the biomass that results from the thorough mixing.

In this regard, it can be useful to apply an insulation layer externally to the pulper and the buffer tank in order to reduce heat losses due to radiation from the heat carrier medium.

Alternatively or additionally, the respective tank can be penetrated by one or more heat exchanger coils which run through the interior of the respective tank or surround it and have the greatest possible surface area by virtue of windings and coils. In the case of the heat exchanger in the buffer tank, the coil would be a cooling coil; in the case of the heat exchanger in the pulper, the coil would be a heating coil. A particularly suitable heat carrier is thermal oil, which is preferably used in the heat circuit.

However, the pulper does not have to obtain its heat exclusively by way of the heat circuit from the buffer tank. Particularly when starting the system, if no slurry is available for cooling as yet, other sources are required for heating the pulper.

One step ahead of the buffer tank, excess heat is available from the reaction tank, which has not only the feed pipe for supplying the slurry, but also a gas pipe by way of which it is connected with the pulper. In the case of excessive pressure in the reaction tank, excess gas - so-called purge gas, in other words cleaning gas - can be discharged from the reaction tank by way of this pipe; this gas is introduced into the pulper and raises the temperature there.

Initially, however, heating in the pulper must take place by way of a connection thereof with a steam generator. Ideally, this steam generator can be the same steam generator that also supplies the reaction tank. The major portion of the energy required for heating the biomass in the pulper is provided by supplying hot steam to the pulper.

In addition, heating up of the biomass in the pulper to its operating temperature of

around 90° C can be made more uniform in that means for thorough mixing of biomass and hot steam are assigned to the pulper. Such means can be stirring mechanisms and mixing mechanisms of different types, for example arrangements of mixing nozzles or also a mechanical stirring mechanism having one or more stirring arms. With particular preference, use can be made of an asymmetrical stirring mechanism which ensures that the biomass is not just moved in a circle, but also forms turbulent flows. In the case of placement of mixing nozzles in the pulper, the purge gas from the reaction tank, in particular, can be introduced into the pulper and thus the energy of the reaction tank can contribute to both heating and blending of the biomass.

Supply of hot steam to the pulper furthermore allows liquefaction of the biomass, so that this does not have to be introduced into the reaction tank by a solids pump, but can, for example, be conveyed by means of a centrifugal pump. This allows appreciably faster charging of the reaction tank and thereby reduces the downtime of the apparatus between two batches. Moreover, the centrifugal pump also represents a more economic alternative to the solids pump.

In a concrete embodiment of the pulper this can have a funnel-shaped bottom by way of which heavy components are separated from the biomass. Sand and sludge will settle at the bottom and are discharged from the pulper, by way of a drain opening at the funnel tip, in the direction of a sand separator.

Finally, it is useful in the sense of ideal capacity utilisation to connect multiple reaction tanks with a common pulper. In this way, filling of the next reaction tank can start during the reaction time of a first reaction tank, until the first reaction tank is emptied again and charging thereof with biomass can start afresh. Preferably, about six reaction tanks are served by one pulper in this manner. The same also applies to the buffer tanks; preferably, two buffer tanks will receive the completely reacted slurry of the six reaction tanks in alternation to one another.

Furthermore, it can be useful in practical implementation not to produce the pulper and/or the buffer tank as an individual construction, but rather to combine multiple tanks, which communicate with one another, to form a pulper or a buffer tank. In particular, tanks obtainable at low cost can be combined to form a tank arrangement in this way, instead of constructing an expensive and particularly large special tank.

The invention described in the foregoing is explained in more detail in the following by way of an embodiment, in which:

Figure 1 is a schematic representation of the method of functioning of apparatus according to the invention and

Figure 2 is a schematic representation of the heat circuit and of the slurry feed.

Figure 1 shows, in a schematic illustration, a reaction tank 1 which is disposed in the centre of the diagram. This tank is connected by way of a feed pipe 8 with a pulper 2, which charges the reaction tank 1 with pre-treated, liquefied biomass. The biomass in the pulper 2 comes from a bunker 6, in which large amounts of biomass are kept on hand. A conveying unit and an impurity separator, particularly a metal separator, which prepares the biomass for the pulper 2, are situated between the bunker 6 and the pulper 2. The demand for one day's operation of all reaction tanks 1 connected with the pulper 2 is in each instance introduced into the pulper 2 by way of a feed pipe 8 and stored there, wherein heated biomass that has been called up is immediately replaced by new, cold biomass from the bunker 6. Hot steam is blown into the pulper 2 by way of a steam generator 4, which is connected with the pulper 2 by way of a steam pipe 11; the steam on the one hand heats the biomass contained in the pulper 2 and on the other hand adds water in order to liquefy the biomass to form a slurry. With the help of an asymmetrical stirring mechanism, which is not shown here, the slurry is thoroughly mixed in the pulper 2 so that uniform heating is guaranteed and the most homogeneous mixture possible results. Sand and sludge from the biomass will settle in the bottom region of the pulper 2. These can be drained into a sand separator 5.

To save heat energy, the reaction tank 1 will deliver so-called purge gas by way of a gas pipe 10 directly into the pulper 2 in the case of excessive pressure, so that the energy escaping from the reaction tank 1 is retained in the system. The reaction tank is also supplied by the steam generator 4 by way of a steam pipe 12 in order to generate the temperature required in the reaction tank 1, the required water and the required pressure and thus to create the reaction conditions for hydrothermal carbonisation.

After the reaction in the reaction tank 1, the slurry with the carbonized biomass is drained into the buffer tank 3 by way of a further feed pipe 8, in which case this can take place by way of at least partial pressure equalisation between reaction tank 1 and buffer tank 3. Because of the pressure gradient between the two tanks 1 and 3, the slurry is drawn into the buffer tank very quickly in this manner and can subsequently cool down therein. After cooling, the slurry passes by way of a further feed pipe 8 to downstream processing 7. During the course of further procedures, which are not considered in detail here, process water 20 separated from the slurry can be returned again to the reaction tank 1, where a further reaction with the still-included organic loads of the process water can be carried out. In addition, in this way the process water is re-used in the process and does not have to be replaced by fresh water.

Overall, the result is that the slurry heats up in the pulper 2 and in the reaction tank 1 and is cooled down in the buffer tank 3. The heat of the slurry in the buffer tank 3 can be transferred to the biomass in the pulper 2 by heat exchangers in the two tanks 2 and 3, which form a heat circuit 9 between these two tanks 2 and 3, so that less energy can escape from the system. This heat energy transferred to the pulper 2 contributes to less hot steam being required in order to keep the pulper 2 at the required temperature.

Figure 2 shows a further schematic diagram in which possible heat exchangers 13 and 14 are shown. On the one hand, there is the possibility of configuring an outer sheath 15 of the tanks 2, 3 with a double wall. Thus, a cavity 16 forms between the two walls and can be covered on the outside with an insulation layer 17 in order to prevent heat losses.

A first heat exchanger 13 in the pulper 2 delivers, by way of the inner wall of the double-walled outer sheath 15, the heat previously absorbed and thereby heats the slurry contained in the pulper 2 when it makes contact with the inner wall in question. In addition, the pulper 2 has a heating coil 18 that passes through the pulper 2 and also gives off heat to the slurry in the interior of the pulper.

A second heat exchanger 14 in the buffer tank 3 fundamentally works in precisely the opposite way while having the same structure; there, the heat carrier that is conducted in the heat circuit 9 absorbs heat from the cooling slurry and transports it to the pulper 2 through the heat circuit 9. Accordingly, the heat transfer coil also functions as a cooling

coil 19.

Thus, described in the foregoing is apparatus for conducting a hydrothermal carbonisation reaction, which is able to improve the energy balance through the use of heat exchangers and the transport of heat through the system and to structure the method to be more effective by means of already preheating and liquefying the biomass in the pulper.

REFERENCE NUMERAL LIST

- | | |
|----|-----------------------|
| 1 | reaction tank |
| 2 | pulper |
| 3 | buffer tank |
| 4 | steam generator |
| 5 | sand separator |
| 6 | bunker |
| 7 | downstream processing |
| 8 | feed pipe |
| 9 | heat circuit |
| 10 | gas pipe |
| 11 | steam pipe |
| 12 | steam pipe |
| 13 | first heat exchanger |
| 14 | second heat exchanger |
| 15 | outer sheath |
| 16 | cavity |
| 17 | insulation layer |
| 18 | heating coil |
| 19 | cooling coil |
| 20 | process water return |

CLAIMS

1. Apparatus for conducting a hydrothermal carbonisation reaction, comprising a reaction tank (1) which is connected with a steam generator (4) to receive hot steam and with a mixing tank by way of a feed pipe (8) to receive biomass and which is connected with a buffer tank (3) to drain off a slurry formed in the reaction tank from hot steam and biomass,
characterised in that the mixing tank is structured as a pulper (2) and comprises a first heat exchanger (13) for delivery of heat to the biomass stored in the pulper (2), the first heat exchanger being connected with a second heat exchanger (14), which is associated with the buffer tank (3), for absorbing heat from slurry drained from the reaction tank (1) into the buffer tank (3), so as to form a closed heat circuit (9).
2. Apparatus according to claim 1, characterised in that wherein the pulper (2) and/or the buffer tank (3) has or have a double-walled outer sheath (15) forming a cavity (16) which is connected with the heat circuit (9) and flowed through by a heat carrier.
3. Apparatus according to claim 2, characterised in that the double-walled outer sheath (15) is surrounded by an insulation layer (17).
4. Apparatus according to any one of the preceding claims, characterised in that the pulper (2) and/or the buffer tank (3) is or are surrounded and/or penetrated by at least one heat exchanger coil (18).
5. Apparatus according to any one of the preceding claims, characterised in that associated with the heat circuit (9) is at least one third heat exchanger by way of which heat is withdrawable from the heat circuit (9) and/or feedable into the heat circuit (9) in targeted manner.
6. Apparatus according to any one of the preceding claims, characterised in that thermal oil is conducted in the heat circuit (9) as heat carrier.
7. Apparatus according to any one of the preceding claims, characterised in that the pulper (2) is connected with the reaction tank (1) not only by the feed pipe (8), but

also by a gas pipe (10) and can be charged with cleaning gas drained from the reaction tank (1).

8. Apparatus according to any one of the preceding claims, characterised in that the pulper (2) is connected with the steam generator (4) for the supply of hot steam by way of a steam pipe (11).

9. Apparatus according to claim 8, characterised in that the pulper (2) comprises means for thorough mixing of biomass and hot steam.

10. Apparatus according to claim 9, characterised in that the means for thorough mixing of biomass and hot steam is an asymmetrical stirring mechanism and/or a mixing nozzle arrangement.

11. Apparatus according to any one of claims 8 to 10, characterised in that a centrifugal pump is associated with the feed pipe (8) between the pulper (2) and the reaction tank (1).

12. Apparatus according to any one of the preceding claims, characterised in that the pulper (2) has a funnel-shaped bottom for the settling of sand and sludge, wherein an outlet associated with the funnel tip is connected with a sand separator (15).

13. Apparatus according to any one of the preceding claims, characterised in that a plurality of parallel identical reaction tanks (1) is associated with the pulper (2).

14. Apparatus according to any one of the preceding claims, characterised in that the pulper (2) and/or the buffer tank (3) is or are in each instance a plurality of preferably identical tank units communicating with one another.