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Thampi et al.

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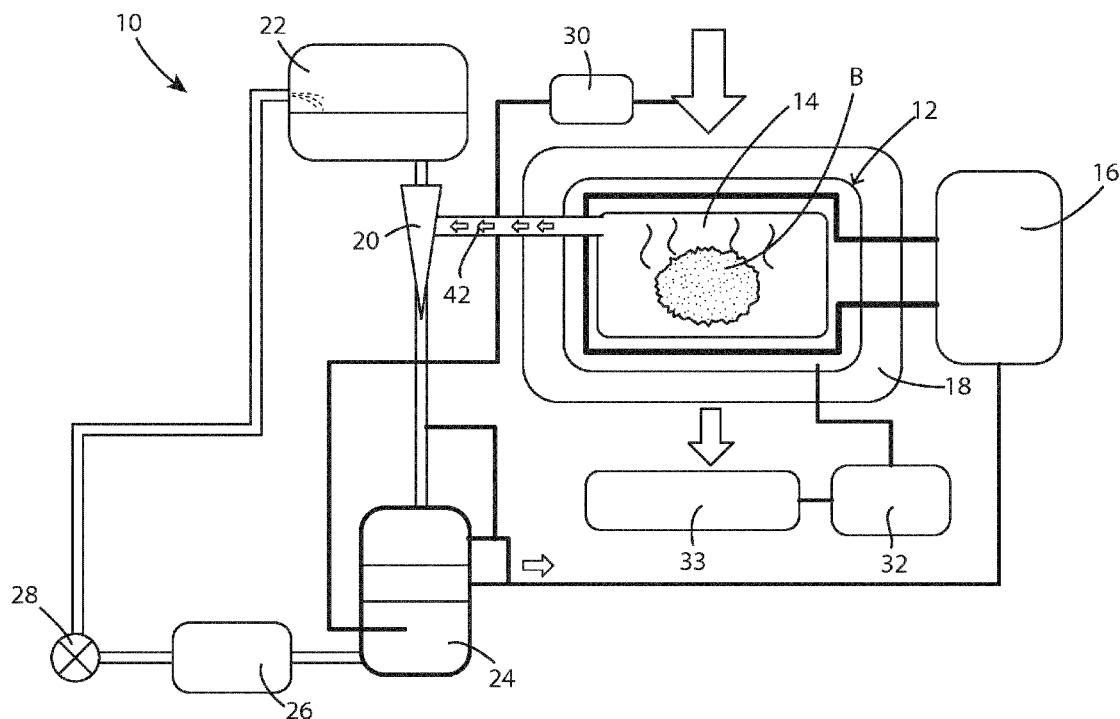
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(57) **ABSTRACT**

This invention relates to a method and apparatus for thermochemically processing material, and in particular relates to the torrefaction of organic material such as biomass, in particular to improve the energy content of the material, the method involving enclosing the material in a reactor which is then evacuated by means of a fluid driven vacuum pump to establish an oxygen free environment within the reactor, heating the material to above 200° C. to liberate process by-products such as volatile gases and/or oils, extracting the liberated volatile gases and/or oils from the enclosure and entraining same within the fluid driving the vacuum pump.



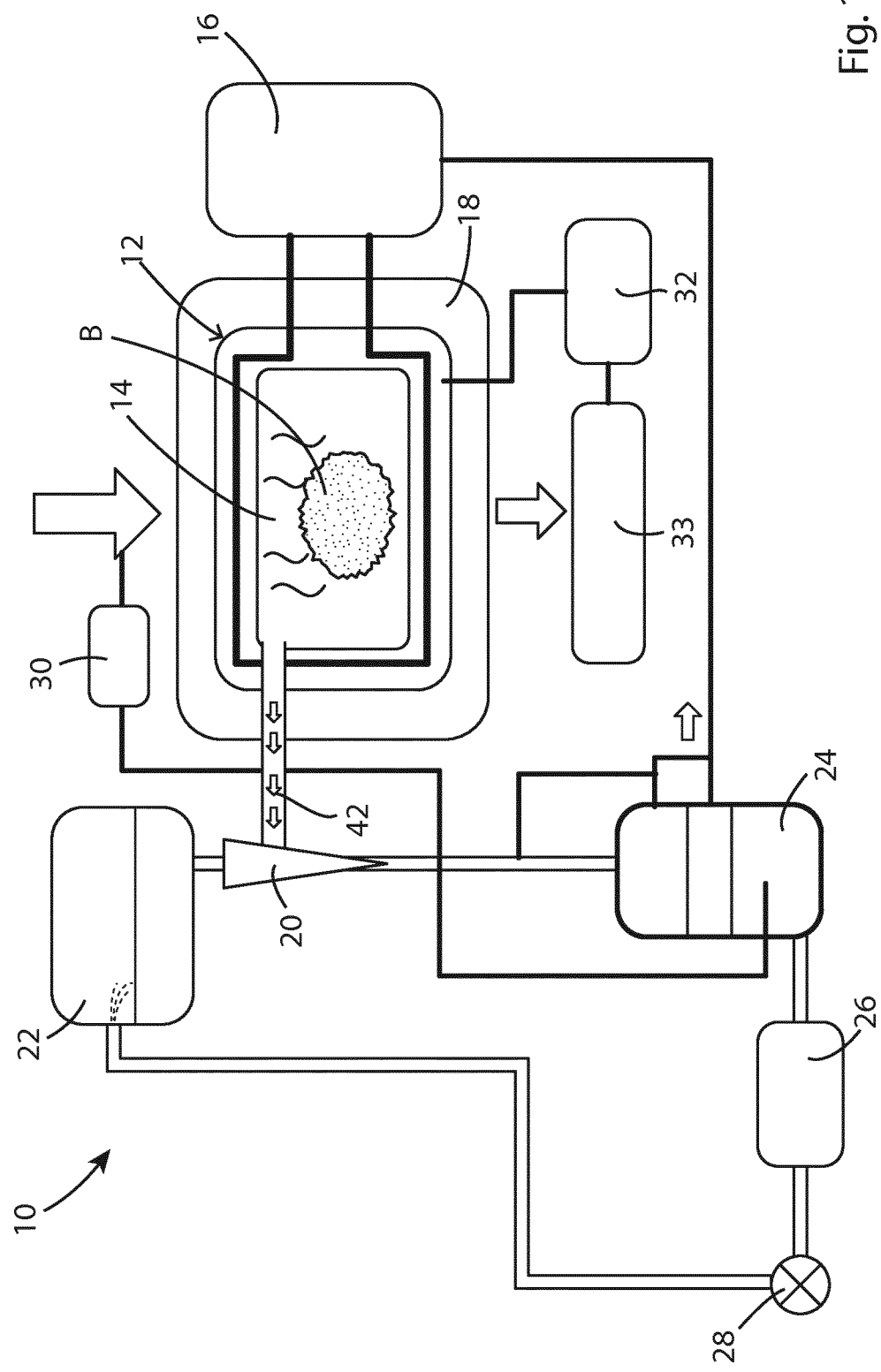


Fig. 1

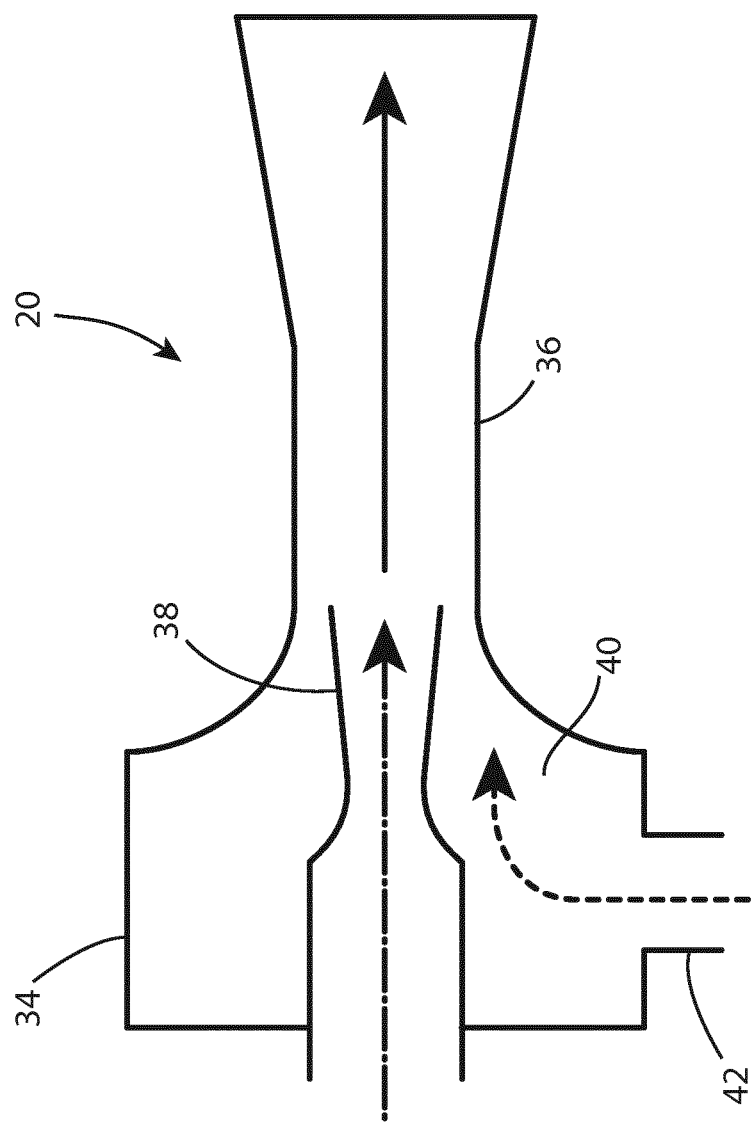


Fig. 2

A METHOD AND APPARATUS FOR THERMOCHEMICALLY PROCESSING MATERIAL

FIELD OF THE INVENTION

[0001] This invention relates to a method and apparatus for thermochemically processing material, and in particular relates to the torrefaction of organic material such as biomass, in particular to improve the energy content of the material in order to improve the performance of the material as a fuel, while also providing additional benefits.

BACKGROUND OF THE INVENTION

[0002] Biomass material such as wood, grasses or straw etc. are suitable materials which could be utilised for energy purposes to replace a proportion of fossil fuel such as coal/peat etc. However, these materials are not ideal for energy purposes in their raw form. Fresh biomass can contain a large proportion of moisture at harvest, and for example Ireland would have been known to reach 65% moisture at harvest but 55% is more typical. This means that biomass is not very suitable for energy purposes without first being dried. There are two methods of drying, force drying requiring energy input and air drying requiring approximately 12-18 months and which only reduces moisture to approximately 30%. Both methods involve a financial cost. However, even when material has been dried, it will act like a sponge and absorb moisture from the surroundings or from the air in high humidity conditions. Therefore, a dried material must be properly stored, again at a financial cost.

[0003] A further issue is the low energy content per kilogram of biomass, generally in the region of 15-18 MJ/Kg when compared to for example diesel (46 MJ/Kg) or coal (24-28 MJ/Kg). This means that for the same amount of energy, a larger quantity of biomass is required.

[0004] As the material is biological, it is prone to decomposers, mould and bacteria, which degrades material and reduces the quality and energy content. This usually happens during air-drying or in storage. The majority of biomass materials are also located far from the end user and are expensive to transport due to their high moisture content, low energy value and low bulk density. In addition, being a natural material, biomass is highly variable and difficult to handle.

[0005] Coal and peat power plants face ever increasing emissions regulations and there is currently only one alternative fuel which can be used in these facilities, biomass. However biomass can only be blended to a maximum of 10-15% with fossil fuels which means it is very difficult to reduce emissions by switching to such a "green" fuel. Some power plants are therefore changing to biomass boilers, but at a very high capital cost.

[0006] The solution is to create a high energy value, dry and therefore cheap to transport and easy to handle, hydrophobic fuel which will not readily degrade during storage.

[0007] Torrefaction is a thermal upgrading process, which converts low quality biomass materials such as wood, grass etc. into a coal like substance known as bio-coal or torrefied biomass. This processing greatly improves the properties of the raw material for combustion, transportation and storage. The torrefaction process removes the heavy, low energy parts of the biomass in the form of a gas/oil resulting in a material which has a mass reduction of up to 30% of its

original weight but which typically retains 80-98% of its original energy content. The gas/oil which is produced from the process can be burnt in order to process the next batch of material i.e. it is possible for the process to feed itself from an energy point of view. The resulting bio-coal is more economical to transport and has more energy per kg than standard biomass fuels.

[0008] The benefits of torrefied biomass are as follows:

[0009] It has higher energy content per kg of material, 20-24 MJ/kg compared to 15-18 MJ/kg for wood pellets.

[0010] It is cheaper to transport and a greater quantity of energy can be transported per truckload, i.e. reduced logistics means reduced cost.

[0011] The point 2 above leads to lower carbon footprint overall.

[0012] The energy required to pulverize torrefied biomass is less than standard biomass.

[0013] It is hydrophobic and will not absorb water, i.e. it can be stored outside like coal.

[0014] It is an inert material, i.e. free from fungal decomposition; it won't degrade when stored or self-ignite in storage, which can be an issue when storing current wood pellets in silos.

[0015] It is one of the only renewables, which can provide stable base load generation as it is easy to store and use on demand, as needed.

[0016] It increases the technical limit for co-firing biomass with coal from 15% max currently to upwards of 60%, potentially 100% without the need to alter any infrastructure, i.e. no capital investment required to switch to bio-coal from current coal. However, capital investment is required for co-firing with standard biomass.

[0017] It is a renewable, CO₂ neutral energy source.

[0018] It can be used to enrich soil or sequester carbon.

[0019] When burnt, the ash can also be used as fertiliser.

[0020] However the thermochemical processing of biomass materials does present alternative problems. In particular the liberation of process by-products such as volatile gases and/or tar is a major issue and due to the complex design of many of the biomass reactors, this tar causes blockages which results in downtime for machinery to be cleaned.

[0021] It is therefore an object of the present invention to provide a system and method for thermochemically processing an organic material and more preferably for the torrefaction of biomass material in an efficient manner.

SUMMARY OF THE INVENTION

[0022] According to a first aspect of the present invention there is provided a method of thermochemically processing a material comprising the steps of;

[0023] retaining the material in a fluid tight enclosure;

[0024] reducing the concentration of oxygen within the enclosure;

[0025] thermally liberating at least one substance from the material; and

[0026] extracting the at least one thermally liberated substance from the enclosure.

[0027] Preferably, the method comprises retaining the material, in a heated state, in the fluid tight enclosure.

[0028] Preferably, the method comprises heating the material following location of the material in the enclosure.

[0029] Preferably, the method comprises heating the material for a period of up to 100 minutes, and more preferably for a period of up to 60 minutes.

[0030] Preferably, the method comprises heating the material to a temperature above 40° C., more preferably to a temperature above 100° C., and most preferably to a temperature above 200° C.

[0031] Preferably, the method comprises reducing the concentration of oxygen within the enclosure to below 20%, more preferably to below 10%, and most preferably to between 0-5%.

[0032] Preferably, the method comprises thermochemically liberating the at least one substance from the material.

[0033] Preferably, the method comprises thermochemically liberating volatile gases and/or oils from the material.

[0034] Preferably, the method comprises the step of reducing the moisture content of the material prior to heating the material.

[0035] Preferably, the method comprises reducing the equilibrium moisture content of the material to between 0-5%, more preferably to between 0-3%, and most preferably to between 0-1%.

[0036] Preferably, the method comprises the step of at least partially evacuating the enclosure to reduce the concentration of oxygen.

[0037] Preferably, the method comprises at least partially evacuating the enclosure by means of a fluid driven vacuum pump.

[0038] Preferably, the method comprises passing a flow of fluid through a venturi in the vacuum pump to generate a reduction in pressure within the pump, and utilising the reduction in pressure to establish a negative pressure differential between the pump and the enclosure in order to at least partially evacuate the enclosure.

[0039] Preferably, the method comprises utilising the negative pressure differential between the pump and the enclosure in order to extract the at least one thermally liberated substance from the enclosure.

[0040] Preferably, the method comprises the step of entraining the at least one thermally liberated substance in the flow of fluid operating the vacuum pump.

[0041] Preferably, the method comprises separating liquid and gaseous phases from the fluid downstream of the vacuum pump.

[0042] Preferably, the method comprises heating the flow of fluid operating the vacuum pump.

[0043] Preferably, the method comprises heating at least a part of the vacuum pump. Preferably, the method comprises reclaiming heat from the fluid.

[0044] Preferably, the method comprises reclaiming heat from the thermochemically processed material.

[0045] Preferably, the method comprises utilising the at least one thermally liberated substance to heat the enclosure.

[0046] Preferably, the method comprises utilising the at least one thermally liberated substance to produce heat for the use in the method.

[0047] According to a second aspect of the present invention there is provided a thermochemical processing apparatus comprising a fluid tight enclosure for retaining a material to be thermally processed; and a vacuum pump arranged to reduce the oxygen concentration within the enclosure.

[0048] Preferably, the apparatus comprises a heating system adapted to heat the enclosure.

[0049] Preferably, the vacuum pump comprises a fluid driven vacuum pump.

[0050] Preferably, the vacuum pump comprises a fluid jet eductor.

[0051] Preferably, the apparatus comprises a phase separation tank downstream of the fluid driven vacuum pump.

[0052] Preferably, the apparatus comprises a heat exchanger arranged to reclaim heat from the separation tank.

[0053] Preferably, the apparatus comprises a heat exchanger arranged to reclaim heat from the material.

[0054] A thermochemically processed product when produced according to the method of the first aspect of the invention.

[0055] As used herein, the term "heated state" is intended to mean that a material is heated to above the local ambient temperature, and that the heating may occur before the material is located in an enclosure, and/or may occur while the material is located in that enclosure.

[0056] As used herein, the term "thermally liberating" is intended to mean liberating one or more substances from a material by the application of heat to the material, and which is intended to cover the thermochemical liberation of substances from the material, and preferably in a sub-atmospheric environment, and which may cover the separation or liberation of moisture from the material and/or other substances such as tars, oils, or other volatile chemicals.

BRIEF DESCRIPTION OF THE DRAWINGS

[0057] The present invention will now be described with reference to the accompanying drawings, in which:

[0058] FIG. 1 illustrates a schematic representation of a thermochemical processing apparatus according to an embodiment of the present invention; and

[0059] FIG. 2 illustrates a cross section of a water jet eductor forming part of the apparatus shown in FIG. 1 and used to evacuate an enclosure within a reactor of the apparatus.

DETAILED DESCRIPTION OF THE DRAWINGS

[0060] Referring now to the accompanying drawings, there is illustrated a method and apparatus for thermochemically processing a material, in particular but not exclusively an organic material such as biomass B, in order to liberate one or more substances from the material, in order to alter the physical and/or chemical composition of the material. It is however to be understood that while a effectively solid material in the form of the biomass B is used to exemplify the invention, the material to be processed could be a combination of solid, liquid or gaseous form. The process may be applied to upgrade or increase the energy content per kilogram (kg) of such material, in order to improve the materials performance as a combustible fuel, or to reduce moisture from the material, or further to extract one or more substances from the material which may then be used for other purposes.

[0061] As mentioned above, one application of the method and apparatus of the invention is to liberate tars, gases and other volatile elements from organic materials in order to increase the energy density of the material. This thermochemical processing is known as torrefaction or slow pyrolysis, depending on the temperature range and heating rate employed during the process, as will be described in detail hereinafter, and is used in upgrading a lower energy

content, wet material such as biomass, into high energy content, dry fuel. The process requires an inert, essentially oxygen free atmosphere along with the application of heat, and preferably a method to remove process by-products produced or liberated during the process. The process works with biomass or other materials in various forms such as saw dust, chips, chunks, pellets and any other forms of biomass such as manure, sludge, food waste, etc. The size of the biomass can be quite variable and the process works best with high surface area material.

[0062] Referring to FIG. 1 there is illustrated a schematic representation of a thermochemical processing apparatus 10 according to a particular embodiment of the invention. The apparatus 10 comprises a reactor 12 which defines an interior enclosure 14 for receiving material such as the biomass B to be thermochemically processed as hereinafter described. While the enclosure 14 may be accessed by any suitable sealable opening (not shown) provided in the reactor 12, once the opening has been sealed in order to begin thermochemical processing, the enclosure 14 is fluid tight.

[0063] The apparatus 10 further comprises or is operatively associated with a heat source 16, which may passively or actively provide heat, and which in the embodiment illustrated is in the form of a conventional boiler, but may take any other suitable form, for example a burner, an electrical element or any other functional equivalent either directly or indirectly employed. The reactor 12 is preferably provided with a suitable layer of insulation 18 in order to minimise heat loss to the environment, and thus increase the efficiency of the process. The reactor 12 is further preferably of the indirect heating type, meaning that mainly conduction and radiation are used to heat the biomass B contained within the enclosure 14, allowing a reduced oxygen content atmosphere, preferably a partial or essentially complete vacuum to be established in the enclosure as will be described hereinafter. As a result the heating medium and biomass B will never mix and will only transfer heat between one another. Convective heating may however be employed, if for example a heated fluid such as water, steam, nitrogen or other inert heated fluid is injected into the enclosure 14. In addition, direct heating via steam/process gas recirculation could be employed, as could volumetric heating, for example through the use of microwave heating.

[0064] The apparatus 10 additionally comprises a vacuum pump, preferably but not essentially in the form of a water jet eductor 20 which is arranged, as will be described in detail hereinafter, to establish a reduced oxygen content environment, and preferably an essentially oxygen free environment, within the enclosure 14 through partial or complete evacuation of the enclosure 14. In the embodiment illustrated the eductor 20 is supplied under gravity from a water storage tank 22, although it will be appreciated from the following description of the operation of the apparatus 10 that any other suitable fluid supply may be provided to the eductor 20, for example through forced flow such as through the use of a pump (not shown) or the like, or by other passive means.

[0065] A separation tank 24 is provided downstream of the eductor 20, the operation of which will be described hereinafter. The separation tank 24 exhausts to a filter 26 and then a pump 28 for recirculating the water or other fluid back to the supply tank 22. It will of course be understood that the various physical components of the apparatus 10 may be repositioned relative to one another, and/or additional com-

ponents added to the apparatus 10, when and if necessary, for example to enable the handling of a larger volume of biomass B or the like as would be the case in a more industrialised embodiment of the apparatus 10.

[0066] Finally, the apparatus 10 preferably comprises a first heat exchanger 30 operable as hereinafter described to reclaim heat from the separation tank 24, and optionally a second heat exchanger 32 operable to reclaim heat from the biomass B within the enclosure 14, once the thermochemical processing of the biomass B has been completed. This process of reclaiming heat from the biomass B may be undertaken in a separate cooling chamber 33 in order to allow a fresh batch of biomass to be located in the reactor 12, effectively permitting the uninterrupted operation of the reactor 12.

[0067] Turning then to the operation of the thermochemical processing apparatus 10, material to be processed, in this case the biomass B, is loaded into the enclosure 14 by any suitable conveying means (not shown). This conveyance could be by passive or active means, for example a passive flow from a hopper (not shown) or the like, or actively, for example by means of conveyor belt (not shown) or the like. The biomass B may be chipped, ground or otherwise processed to an appropriate size for ease of use and conveyance into and out of the reactor 12. To this end suitable conveying means (not shown) may be provided as part of the apparatus 10 in order to perform this function. Depending on the condition of the processed biomass B, a precursor drying stage may be performed in order to reduce the moisture content to approximately 0%. This drying process may be performed independently of the apparatus 10, or may be performed using the reactor 12. The drying process is preferably performed as a natural precursor to the thermochemical processing of the material, as the temperature within the reactor 12 rises from ambient to above 200° C.

[0068] Once the material has been dried and is sealed, or remains sealed, within the reactor 12, the water jet eductor 20 or corresponding vacuum pump is actuated by permitting water or any other suitable fluid to flow from the supply tank 22 through the eductor 20, which is illustrated in more detail in FIG. 2. The eductor 20 comprises a main body 34 which defines a convergent divergent nozzle 36 into which the supply of water or other fluid, for example a gas, is directed, from the supply tank 22, via a fluid injection nozzle 38 formed within the body 34 and whose outlet is spaced from the entrance to the convergent divergent nozzle 36. The body 34 further defines a gas inlet 40 which is in fluid communication with the entrance to the convergent divergent nozzle 36 and which is also in fluid communication with a conduit 42 connected between the main body 34 and the enclosure 14. Thus the conduit 42 can be considered as part of the vacuum pump, in particular where reference is made below to heating the vacuum pump eductor 20.

[0069] Thus in use water or other fluid flows under the influence of gravity, or by any other suitable means, from the supply tank 22 to issue as a jet from the fluid injection nozzle 38. This fluid then enters the convergent divergent nozzle 36 and is accelerated, thereby reducing the pressure of the water or other fluid and creating suction at the entrance to the convergent divergent nozzle 36. This suction creates a negative pressure differential between the gas inlet 40 and the enclosure 14, which will thus serve to evacuate the enclosure 14, thereby generating a reduced oxygen environment therein.

[0070] It will also be appreciated, as described in greater detail hereinafter, that any process by-products such as gases and/or oils liberated from the biomass B within the reactor 12 will be drawn out of the enclosure 14 due to this negative pressure differential, and will thus become entrained within the flow of fluid passing through the eductor 20. Thus the eductor 20 serves a dual purpose, simultaneously evacuating the enclosure 14 while also extracting liberated gases and/or oils from the material being processed. The fluid moving through the eductor 20 therefore acts as a conveyor to remove gases and/or oils from the reactor 12. The fluid flowing through the eductor 20 may also be heated, whether passively or actively, in order to prevent any condensation of tars or the like on the interior of the eductor 20 or related downstream components or the like. Similarly the eductor 20 and/or the conduit 42 may be heated to achieve the same effect. It should be noted that a reduced oxygen environment could be established within the enclosure 14 by other suitable means, for example by purging oxygen from the enclosure 14 with an inert gas such as nitrogen or argon or the like. However the use of evacuation is the preferred methodology. It should also be noted that the creation of a vacuum has the additional benefit of reducing the energy required to dry the material to be processed. While water boils at 100° C. at one atmosphere of pressure, under reduced pressure or in a vacuum water will boil at much lower temperatures depending on the pressure achieved, thereby reducing the energy requirements for the drying stage, if performed in the reactor 12.

[0071] Once the eductor 20 is operational and has established an oxygen free environment within the reactor 12, the temperature within the enclosure 14 is gradually raised to between 200° C. and 300° C. for a period of time, which will vary depending on the material and/or quantity thereof being processed, and for example may be for a period of up to 100 minutes. This interval is dependent on the initial material properties such as size, moisture content, type of biomass and the size of the reactor 14. If the biomass B has been pre-dried to 0% moisture the process takes between 15-60 minutes at the said temperature. Heating of the biomass B for the above mentioned period will cause hot volatile gases to be emitted from the material, along with vapours, oils/tars or the like. These liberated gases and/or oils are immediately extracted from the enclosure 14 through the evacuating action of the eductor 20, which will additionally serve to entrain the gases and/or oils in the flow of water or other fluid passing through the eductor 20. The resulting mixture is preferably processed downstream of the eductor 20 in order to extract the various products, possibly for recycling for use within the process, or for separate use, such as those found in a bio-refinery or for the sale of aromatic oil compositions. It should be noted, in particular if a gas is used as the process fluid flowing through the eductor 20, that the gas exiting the eductor 20 and having the liberated volatile gases/oils entrained therein, may be combusted directly without any processing or separation. A fluid take off line 44 may therefore be provided directly downstream of the eductor 20, and may as illustrated lead directly to the boiler 16 in order to supply the fluid/gas to the boiler for combustion.

[0072] It is also envisaged that the heating of the biomass B, or other material being processed, may occur prior to the

material being introduced into the reactor 14, or the material may be heated to a first temperature outside of the reactor 14, and then heated to the final process temperature within the reactor 14. This temperature will depend on the desired one or more substances to be liberated from the material, for example a lower temperature being necessary for the liberation of moisture, while a higher temperature will be required to liberate volatile gases and tars or the like.

[0073] Once a suitable heating time has elapsed the processed or torrefied biomass is allowed to cool, preferably in the dedicated cooling chamber 33. The reactor 12 may be maintained at temperature if operating continuously, or may be allowed to cool if operating by batch. The second heat exchanger 32 may be employed at this stage to capture the heat emitted from the biomass B as it cools and this captured heat may then be reused within the process or elsewhere.

[0074] Similarly heat transferred from the enclosure 14 into the flow of fluid operating the eductor 20 may be recycled for further use, for example to be fed back into the process of the invention, and most preferably in order to effect the pre-process drying of the material. In the embodiment illustrated the heated water enters the separation tank 24, with which the first heat exchanger 30 is associated, allowing the heat within the water or other fluid to be reclaimed from the separation tank 24. The separation tank 24 may also be used to allow the gas, oil and liquid phases to separate, and from where the gas and oil phases may be withdrawn for further use. For example the gas/oil products may be combusted in order to generate heat for use within the process of the invention. The separated water phase is then passed through the filter 26 before being pumped back to the water supply tank 22 for recirculation through the eductor 20.

[0075] The process and apparatus 10 of the present invention thus provide a means of thermally liberating one or more substances from a material, for example to create a high energy value fuel with a reduced hydrogen to carbon ratio and reduced oxygen to hydrogen ratio than the parent feedstock, which is dry and thus cheaper to transport, easier to handle, is hydrophobic and will not readily degrade during storage. In addition the problem of the condensation of tar on the internal components of the apparatus 10 is overcome by using the eductor 20 to both generate a vacuum within the enclosure 14 while simultaneously withdrawing the tars, gases and other volatile elements liberated from the processed material, which are then entrained within the fluid used to create the vacuum, thus preventing their condensation on the internal components of the apparatus 10.

[0076] The thermochemically processed end product, in particular torrefied biomass, is quantifiable in a number of ways, for example the calorific fuel value, colour, mechanical properties, hydrophobic properties, oxygen, hydrogen and carbon ratios. The process of the invention reduces the oxygen to hydrogen ratio and increases the carbon to hydrogen ratio, which is an indicator of the fuel quality, resulting in increased energy density/unit mass (Kg) or unit volume (L). The level of aromatics (cyclics and poly-cyclics) is also an indicator. The hydrophobic properties may also be used as an indicator.

[0077] In terms of specific values, the energy content/calorific value of the thermochemically processed material can range from dry wood at 18 MJ/kg, up to 38 MJ/kg depending on the raw material used. If coconut shell is used, it would be expected to be at the higher end of the scale. The

process can also be used to dry low energy content materials such as wet wood, grasses and potentially even slurry, which can have energy contents as low as 4 MJ/kg. This is quite a large range as the process will dry & carbonise any organic material (or plastics, rubbers etc.) resulting in an energy densification per kilogram depending on the dry energy content of the raw material. e.g. wet wood at 50-55% water (harvested form) has an energy content of 5-6 MJ/kg but if 100% dry has an energy content of roughly 18 MJ/kg. These values are also only representative of an organic input range. Rubber, for example from used car tyres, plastics etc. would have a different energy density following thermochemical processing according to the invention.

[0078] The embodiment described above focuses on a temperature range of between 200° C.-300° C., for torrefaction, which results in up to approximately 35% energy densification. If the temperature were raised to 450° C. more of the material would be converted to volatile by-products, leaving the higher energy components in solid form. This is the reason charcoal has such a high energy value per kg of 30 MJ/kg. It begins as fresh wood at 5/6 MJ/kg at harvest, is dried to 18 MJ/kg, then carbonised severely, which converts roughly 60-70% of its mass to gas resulting in charcoal at 30 MJ/kg. The higher the process temperature the more material is converted to volatile by-products and so a higher level of energy densification takes place. This is however true only when the process is intended to produce a solid fuel as the main product. If the process uses extreme temperatures or oxygen partial pressure limits, then a loss in energy density occurs, with the extreme case of just ash and/or char being produced. The method and apparatus of the invention are also applicable to gasification and/or pyrolysis at high temperatures of up to approximately 1200° C.

[0079] The process and reactor 10 of the present invention also provide a reduced risk of fire and/or explosion due to the reduced oxygen concentration employed, and the continuous removal of the volatile oils and gases from the reactor 10. Conventional torrefaction reactors have a relatively high risk of fire and/or explosion due to the high oxygen concentrations and the presence of the liberated oils, waxes and other materials, which pose a fire hazard and which may also act to clog the reactor components, further increasing this risk. These issues are significantly reduced with the reactor 10 of the present invention.

1. A method of thermochemically processing a material comprising steps of:

- retaining the material in a fluid tight enclosure;
- reducing the concentration of oxygen within the enclosure;
- thermally liberating at least one substance from the material; and
- extracting the at least one thermally liberated substance from the enclosure.

2. A method according to claim 1 comprising retaining the material, in a heated state, in the fluid tight enclosure.

3. A method according to claim 1 comprising heating the material of after retaining the material in the enclosure.

4. A method according to claim 3 comprising heating the material for a period of up to 100 minutes.

5. A method according to claim 1 comprising heating the material to a temperature above 40° C.

6. A method according to claim 1 comprising reducing oxygen concentration within the enclosure to below 20%.

7. A method according to claim 1 comprising thermochemically liberating the at least one substance from the material.

8. A method according to claim 1 comprising thermochemically liberating volatile gases and/or oils from the material.

9. A method according to claim 1 comprising the step of reducing moisture content of the material prior to heating the material.

10. A method according to claim 9 comprising reducing an equilibrium moisture content of the material to between 0-5%.

11. A method according to claim 1 comprising the step of at least partially evacuating the enclosure to reduce oxygen concentration.

12. A method according to claim 11 comprising at least partially evacuating the enclosure with a fluid driven vacuum pump.

13. A method according to claim 12 comprising passing a flow of fluid through a venturi in the vacuum pump to generate a reduction in pressure within the pump, and utilising the reduction in pressure to establish a negative pressure differential between the pump and the enclosure in order to at least partially evacuate the enclosure.

14. A method according to claim 13 comprising utilising the negative pressure differential between the pump and the enclosure in order to extract the at least one thermally liberated substance from the enclosure.

15. A method according to claim 14 comprising the step of entraining the at least one thermally liberated substance in the flow of fluid operating the vacuum pump.

16. A method according to claim 15 comprising separating liquid and gaseous phases from the fluid downstream of the vacuum pump.

17. A method according to claim 12 comprising heating the flow of fluid operating the vacuum pump.

18. A method according claim 12 comprising heating at least a part of the vacuum pump.

19. A method according to claim 12 comprising reclaiming heat from the fluid.

20. A method according to claim 1 comprising reclaiming heat from the thermochemically processed material.

21. A method according to claim 1 comprising utilising the at least one thermally liberated substance to heat the enclosure.

22. A method according to claim 1 comprising utilising the at least one thermally liberated substance to produce heat for the use in the method.

23. A thermochemical processing apparatus comprising:
a fluid tight enclosure for retaining a material to be thermally processed; and
a vacuum pump arranged to reduce the oxygen concentration within the enclosure.

24. A thermochemical processing apparatus according to claim 23 further comprising a heating system adapted to heat the enclosure.

25. A thermochemical processing apparatus according to claim 23 wherein the vacuum pump comprises a fluid driven vacuum pump.

26. A thermochemical processing apparatus according to claim 25 wherein the vacuum pump comprises a fluid jet eductor.

27. A thermochemical processing apparatus according to claim 25 further comprising a phase separation tank downstream of the fluid driven vacuum pump.

28. A thermochemical processing apparatus according to claim 27 further comprising a heat exchanger arranged to reclaim heat from the separation tank.

29. A thermochemical processing apparatus according to claim 23 further comprising a heat exchanger arranged to reclaim heat from the material.

30. A thermochemically processed product produced according to the method of claim 1.

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