SUKHDEEP SINGH RANA

INDIAN PATENT APPLICATION NO. …….202211019765

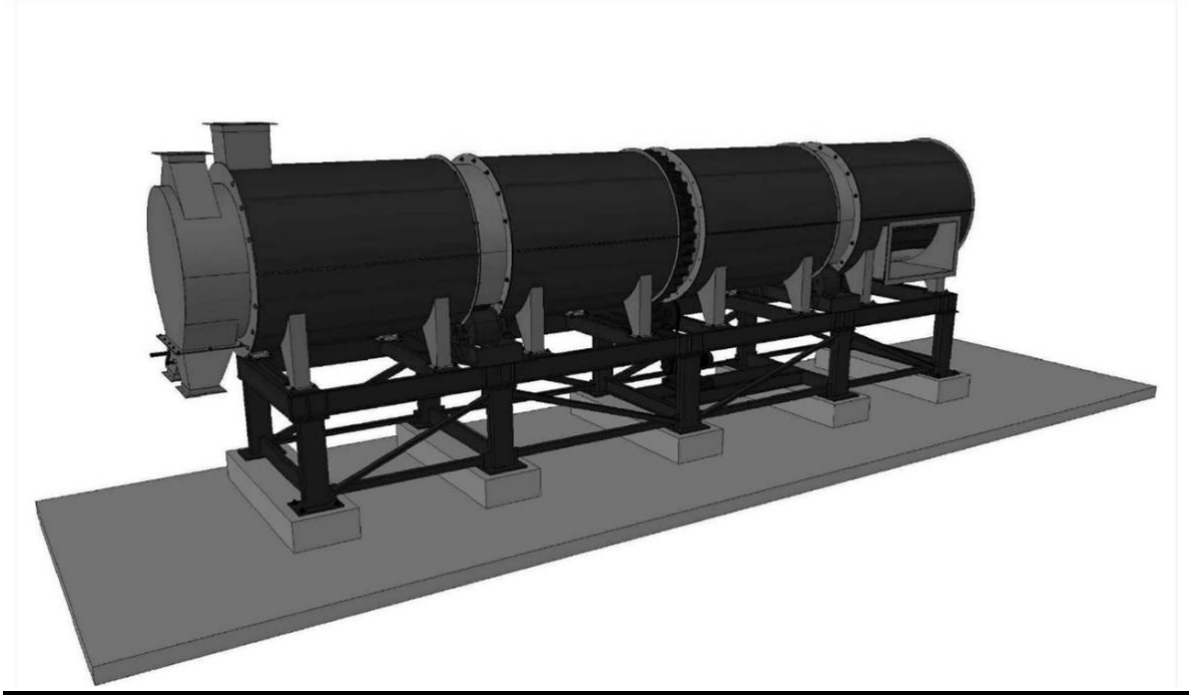


FIG. 1

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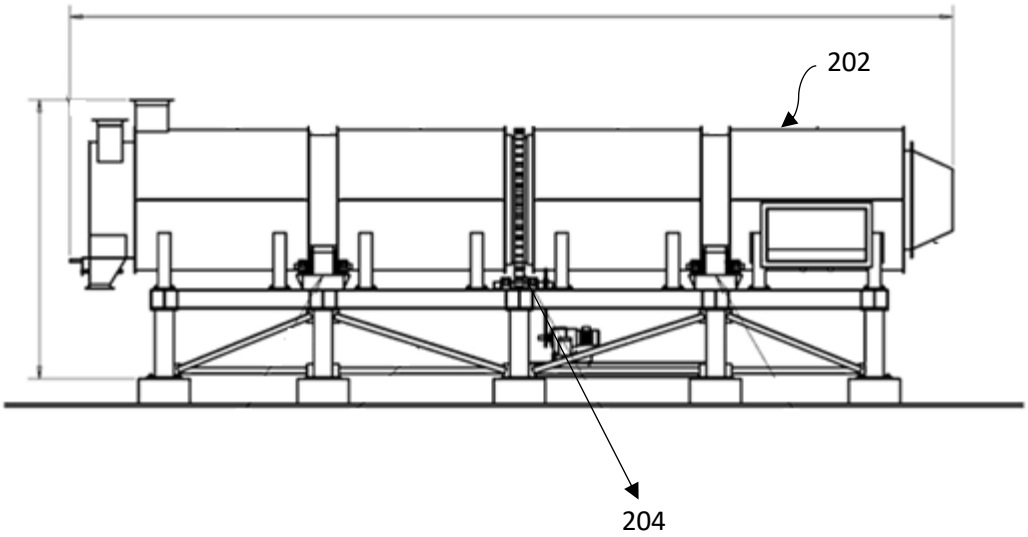


FIG. 2

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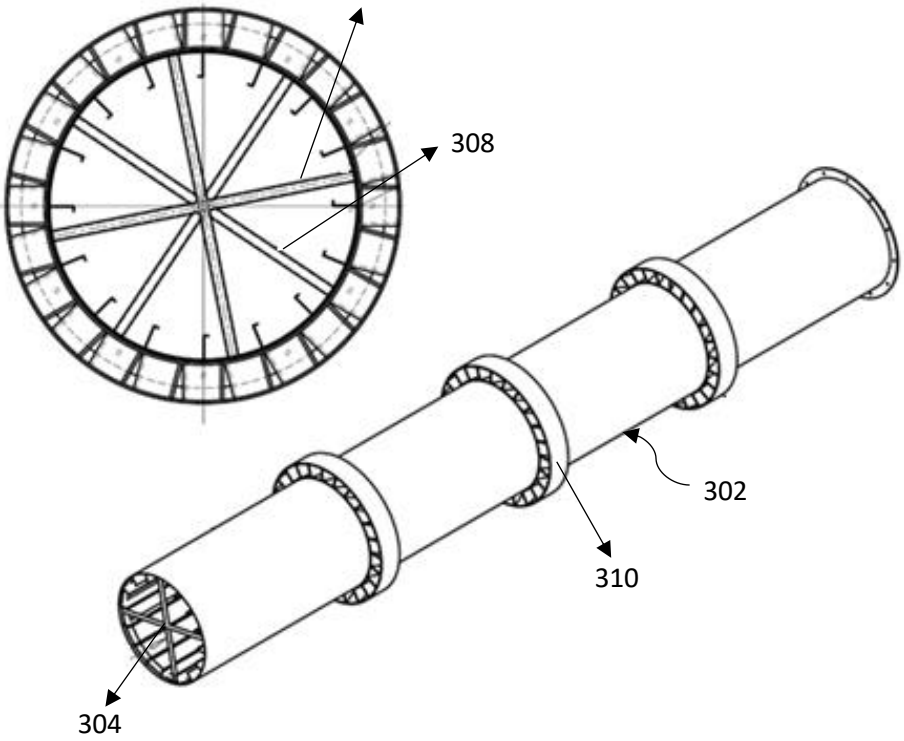


FIG. 3

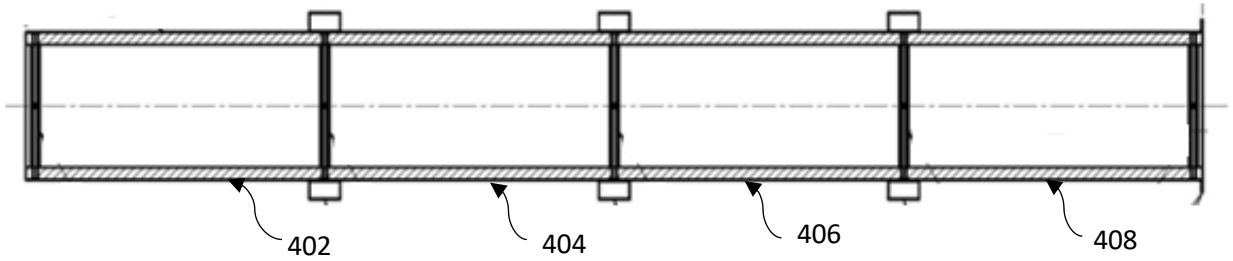


FIG. 4

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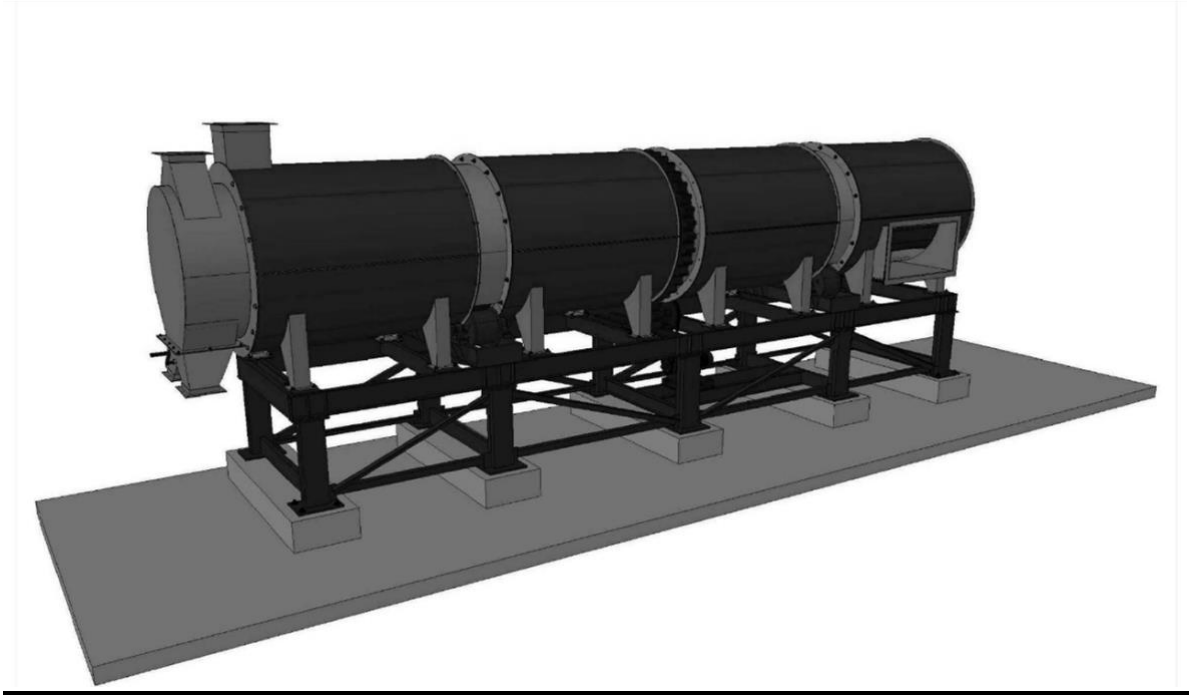


FIG. 1

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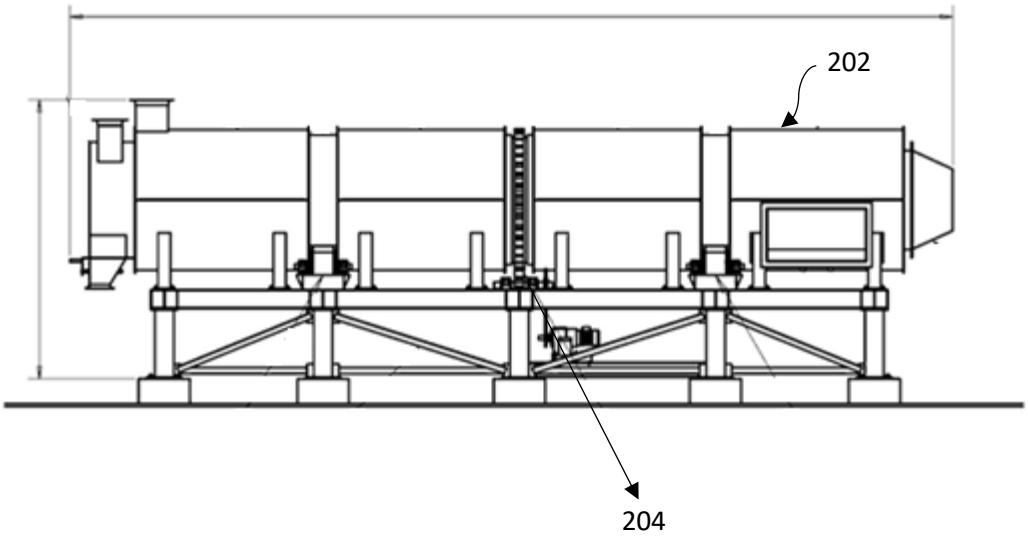


FIG. 2

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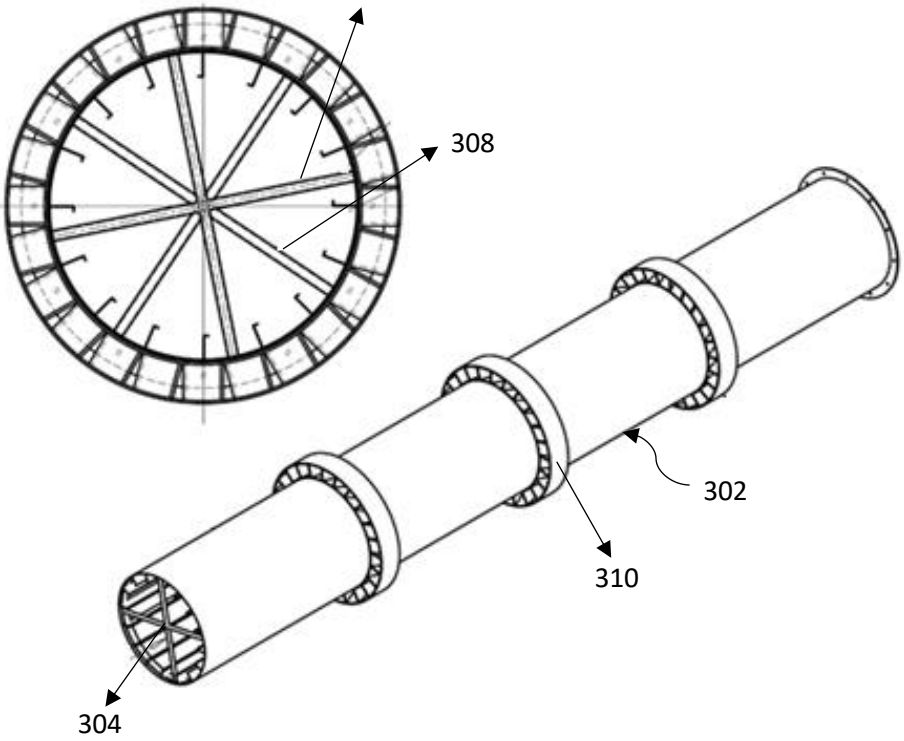


FIG. 3

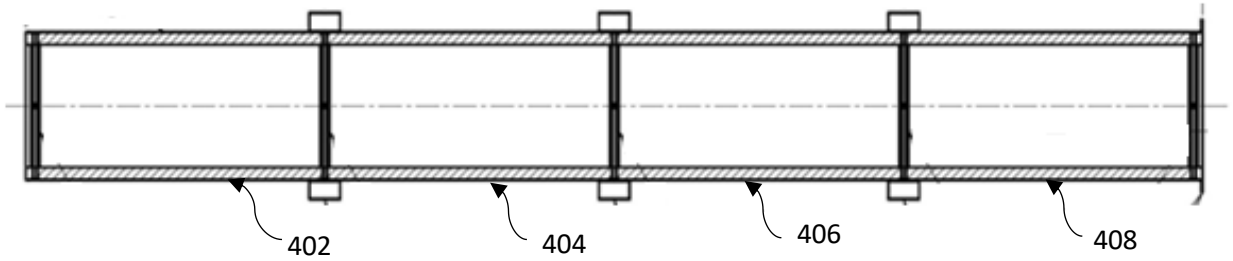


FIG. 4

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FORM 2

THE PATENTS ACT, 1970

[39 OF 1970]

&

THE PATENTS (AMENDMENT) RULES, 2006

COMPLETE SPECIFICATION

[See Section 10; rule 13]

1. TITLE OF THE INVENTION

"A ROTARY TORREFACTION DEVICE"

2. APPLICANT(S)

(a) Name	:	SUKHDEEP SINGH RANA
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(c) Address	:	76, Hemkunt Colony, Greater Kailash Part-I, New Delhi – 110048, India

3. PREAMBLE OF THE DESCRIPTION

The following specification particularly describes the invention and the manner is which it is to be performed.

FIELD OF INVENTION

[001] The present invention is generally related to thermochemical processes. More particularly, the present invention relates to designs and methods for torrefaction processes.

BACKGROUND OF INVENTION

[002] Torrefaction is a thermo-chemical treatment process of biomass, which may typically be executed at 200-350 °C, in the absence of oxygen or with a very low level of oxygen, at atmospheric pressure with low particle heating rates. The torrefaction process causes a biomass to partly decompose, creating torrefied biomass or char, also referred to as 'bio-coal'.

[003] Torrefied biomass is the most elegant solution to convert raw biomass into a coal-like material. The process may involve the heating of biomass with limited oxygen to a temperature of typically 200 to 300°C. Torrefaction generally enhances the fuel properties. The resultant product has better fuel characteristics than the original biomass.

[004] Considerable research has been done on torrefaction of biomass to make it more energy dense, to reduce moisture thereby enhance hydrophobicity, improve flow, transportability and storage. The raw biomass has above concerns, plus, high oxygen content, rigidity, mechanical strength issue, poor flow and fluidization properties, feeding difficulties, hydrophilic tendencies, soot formation, deterioration, lower energy yield and severe handling, transport costs and storage issues which are adequately addressed through torrefaction.

[005] In the Indian context, commercially established and proven cost-effective technology has been till now not achieved. Internationally, a handful of companies have developed torrefaction technologies on pilot scale and select few on commercial scale projects using multiple design technologies with mixed results. One aspect which is common is the high and at times prohibitive cost of adopting the same especially in the Indian context.

[006] To put the ramifications of what has been developed under the Make in India prerogative is a decentralized modular rotary torrefaction system with proven results at a fraction of the cost of such systems worldwide.

[007] The global scenario is that biomass is the fourth largest available fuel resource and accounts for 18% of the greenhouse emissions due to burning of bio mass in raw state.

[008] Indian scenario is perfectly amenable to biomass renewable energy availability of 600 million tons annually coupled with other forest and industrial waste convertible as per NuGreen patented technologies of about 400 million tons.

[009] Crop burning especially rice straw is the biggest challenge with 140 million tons of straw being generated annually. The 10% co-firing of torrefied rice straw can convert the entire thermal plants to this renewable energy source and bring down coal consumption accordingly. The other crop residues if added to this chain a significant portion of coal can be converted into co-fired torrefied biomass. Use of torrefied biomass in co-firing in higher proportions than 10% is easily possible and without changes to the existing coal handling systems.

[0010] As per the revised policy of Ministry of Power on biomass utilization for power generation through co-firing in coal based in thermal power plants it is mandatory for them to mix torrefied biomass in the percentage of 5, 7 and 10 in the first, second and third year respectively which translates to approximately, 35, 50 and 70 million tonnes of torrefied biomass being used. Thus the torrefaction technology serves as an immensely useful tool and no parallel economic solution compensates for the same.

[0011] Multiple objectives of money to the farmer, the environment protection and having economic high energy fuel at low cost to replace fossil fuels.

[0012] Some very complex torrefaction technologies have been tried all over the world. For the long-term sustainability, there are established criteria, majority of which need to be satisfactorily addressed for technical, operational and economic feasibility.

[0013] Non-torrefied material suffers from inherent limitations; hence co-firing torrefied biomass is predominantly preferred.

[0014] Below listed problems have been major issue in torrefaction of the biomass:

[0015] 1. Grind ability is a major issue, as HGI is well before desired level. It is usually between 20-30.

[0016] 2. Intent to pass through 3 mm mesh, the entire material becomes a challenge as well, especially as pellet size mentioned is up to 25mm. Unless finely ground in the first place this is a near impossibility.

[0017] 3. General perception is that only 5 percent is being added but overall tonnage is so high that this 5 percent becomes a major figure.

[0018] 4. The ash limitation has been prescribed earlier at 20 percent primarily to accommodate rice straw and now this is done away with. A very difficult operational situation is thus precipitated. Clinker formation can be severe. This problem is further accentuated by allowing using of many other additional materials to the extent of 25 percent including press mud, etc. This combined with no ash limitation, the usability of the product becomes counterproductive. The oxygen as well as heat intake becomes imperfect, accentuating the grind ability uniformly as well as complete combustion, particle size reduction and so on.

[0019] 6. The temperature profile for ignition is further compromised and lowered and the required temperature profile with co-firing of coal is affected to the detriment of the entire heat balance. Becomes a severe bane to be able to use biomass thus made.

[0020] 7. Co-firing particle size post the grinding along with coal just is not possible and the cost of grinding is high and unproductive as well.

[0021] 8. The pressure required for co-firing is also mitigated and velocity of the joint material, there is a mismatch between biomass thus made and used and coal.

[0022] 9. The moisture of the biomass has to be low for several reasons of heat balance, grind ability, more uniform particle size with significant degree of brittleness. With the moisture levels allowed at times 14-15 percent, this does not allow effective use and makes the use of pellets a fate accompli with failure written it.

[0023] 10. World over torrefaction or roasting of the biomass is the norm. Google direct and first interpretation of torrefaction as we type it out is “bio-coal”. But we are not making bio-coal as the inherent properties thus achieved are nowhere translated in the specifications which have been developed and enumerated. This massive anomaly and

contradiction of the basic tenets of what is to reside material and its advantages gets negated ab initio.

[0024] Now comes the pelleting Vs biomass conversion and direct use in non-pelletized form. For thermal applications 700 million of coal being used. Just 5 percent of that is 35 million tons of biomass use going over 50 million tons is 2 years.

[0025] Typically, 1 ton of pellets consumes about 100 Kw of energy in making and then we are against pulverizing the same before use. So, in effect a huge quantum of power being used to produce power in a cleaner manner. This is being defeated at the outset itself.

[0026] It is pertinent to note that densification has its advantages but in thermal plants the densified material is again pulverized before use.

[0027] To torrefy 1 ton of biomass, the equivalent energy consumed is about 5 Kw or 1/20th of pelleting.

[0028] Thus, serious thought and impetus needs to be given to enabling use of torrefied biomass for direct firing at a point amenable for effective use.

[0029] The selection of agro-residues also is a key factor for maximizing the yield post torrefaction. The composition of the biomass becomes a crucial element as torrefaction essentially is reducing the moisture and removing the low volatiles. Unlike coal which has a linear mass to weight profile biomass is totally different with the elements comprising the biomass having different mass to energy capability. That is why for what is lost in terms of weight much more is gained in terms of energy density.

OBJECTIVE OF THE INVENTION

[0030] It is an objective of the present invention to design a torrefaction device that consumes minimum space and generates low cost of conversion, thereby providing an efficient and cost-effective device.

[0031] It is an objective of the present invention to design a torrefaction device that is not only economical and environmentally friendly but cost effective as well.

[0032] It is an objective of the present invention to design a torrefaction device that avoids use of fossil fuels to produce heat for the thermal process in the torrefaction.

[0033] It is an objective of the present invention to design a torrefaction device that is simple and convenient for further ensuring ease of flow of material.

[0034] It is further an objective of the present invention to design a torrefaction device that allows for maximum feed at any given time and thus allows for maximum output, hence increasing the operational efficiency of the device.

[0035] Further, it is also an objective of the present invention to design a torrefaction device that reduces moisture content in the fuel production, and aims to reduce the moisture to between 2% or 3% and impactfully decompose the low energy hemi-cellulose without disturbing the composition of the cellulose and high energy dense lignin.

[0036] Furthermore, it is also an objective of the present invention to design a torrefaction device that reuses each and every by-product (e.g., gases, other fluids used in the device) for reducing waste products and increasing efficiency. For example, the design of the torrefaction aims to re-use the heat used to heat the biomass, water used to cool the end product, flue gases (excessive moisture or evaporated steam), etc. back into the device.

[0037] It is also an objective of the present invention to produce torrefied biomass that has sufficiently high heating value, higher yield, low residence time, low moisture content, high moisture resistance as well as a high transport and energy density in order to be a suitable clean coal substitute.

[0038] It is an objective of the present invention for being capable of running continuously on 24h/7d basis without releasing volatile organic compound (VOC) as emissions.

[0039] It is also an objective of the present invention to design an easy-to-operate process controls that requires only a small crew of operators and minimum maintenance.

[0040] It is also an objective of the present invention to produce torrefied biomass, using pyrolysis residence times that are short enough to ensure adequate throughput and high yield.

[0041] An objective of the present invention is to be able to accept feedstock that is of standard industry sizes that do not need special pre-treatment such as pulverization or excess drying.

[0042] Another objective of the present invention is to employ automated process controls in order to maintain temperatures within ranges that will foster complete mild pyrolysis of the woody biomass.

[0043] Yet another objective of the present invention is to employ process controls that can adjust easily to various mixtures of woody biomass feeds without adversely impacting production efficiency or quality of the torrefied biomass produced.

[0044] It is an objective of the present invention to produce torrefied biomass that is uniform and that can also be pelletized or reformed into briquettes.

[0045] It is an objective of the present invention to facilitate a scale-up to higher capacity levels at a later date. In other words, the cost of a torrefaction plants with the capacity of producing 10,000 metric tons per year of torrefied biomass should not double if a later scale-up to 20,000 metric tons per year is undertaken

[0046] It is an objective of the present invention to be versatile to convert raw biomass into torrefied biomass and alternatively convert biomass pellets into torrefied pellets.

[0047] It is another objective of the present invention to remove the infirmities of the raw biomass and enable the Effective Oxidative Torrefaction, which is a combination of at least the following variables:

1.Particle size

2.Input moisture

3.Composition of the biomass especially the hemi-cellulose

4.At what point to stop and not overdo torrefaction?

5.The temperature profile of the biomass

6.The residence time versus the temperature profile

7.The yield curve based on what biomass given the choice to prefer for optimization.

8.The understanding of pelleting and its implications for effective torrefaction

9.Selection of inputs which have inherently higher levels of energy release.

10.Mass to energy curves of the components of the biomass to maximize the advantage.

11.To channelize the flue gases to achieve maximum waste heat utilization at multiple points and reduce the already reduced cost of torrefaction.

[0048] Key elements or overriding advantages of torrefaction stand at the outset itself defeated as the norms of moisture below 5 percent, grid ability with less than 1/5 of the power for raw biomass, ability to co-fire higher percentages, particle size reduction with the enabled torrefied material of well over HGI index of 50, the H/C and O/C ratios conducive for combustion with higher carbon and lesser oxygen, the higher ignition temperature possible with torrefied material due to these more apt ratios all get defeated.

[0049] Torrefied biomass allows for use significantly more effectively as:

[0050] - HGI above 50

[0051] - Grind-ability at about 15 percent or normal power

[0052] - O/C ratio more suitable as oxygen significantly reduced

[0053] - ignition temperature gets elevated from 180-degree C to between 220-280-degree C depending on the material

[0054] -moisture well below 5 percent allowing better heat efficacy and pneumatic movement of material as with pulverized coal and ability to achieve near desired pressure levels more suitably.

[0055] In short becoming more coal like.

[0056] Further, as mentioned above, to torrefy 1 ton of biomass, the equivalent energy consumed is about 5 Kw or 1/20th of pelleting. In firing the torrefyer, again predominantly biomass is used. Thus, under a closed loop arrangement, as adapted by the present invention, the flue gases are recycled and essentially fire the torrefyer heat requirement.

[0057] The present invention enables the use of torrefied biomass for direct firing at a point amenable for effective use. Where pelleting has to be done, the model has to pelletize and then torrefy for maximum results and even torrefaction.

[0058] To further clarify advantages and features of the present invention, a more elaborate description of the invention will be rendered by reference to specific embodiments thereof, which is illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope.

SUMMARY OF INVENTION

[0059] An aspect of the present invention provides torrefaction method, comprising: (a) semi-drying a raw material using waste heat by blending of the raw material with the waste heat into a mixer-blender; (b) feeding the waste heat and the semi-dried raw material from the mixer-blender in (a) into a feeding conveyor to further reduce a moisture profile of the semi-dried raw material prior to feeding into a torrefaction device; (c) feeding balance waste heat from the mixer-blender in (a) and the feeding conveyor in (b) along with the further dried raw material in (b) into a biomass furnace to further reduce the moisture profile of the raw material prior to feeding into the torrefaction device; and (d) conveying the raw material after pre-heating in (a), (b) and (c) into at least one inner rotary drum of the torrefaction device for breaking down the raw material while passing from one end to another end of the at least one inner rotary drum, and feeding heat in addition to the waste heat into an annular space between the at least one inner rotary drum and at least one outer stationary drum surrounding the at least one inner rotary drum of the torrefaction device for removing moisture and other volatile matters in the raw material in order to torrefy the raw material, wherein the at least one inner rotary drum rotates while the heat is passed into the annular space and the at least one outer stationary drum is stationary.

[0060] Another aspect of the present invention provides a device for torrefying a raw material, comprising: at least one inner rotary drum which rotates and receives pre-heated raw material for breaking down the raw material while passing from one end to another end of the at least one inner rotary drum; and at least one outer stationary drum surrounding the at least one inner rotary drum for allowing flow of heat into an annular space between the at least one inner rotary drum and at least one outer stationary drum for torrefying the pre-heated raw material into the at least one inner rotary drum; wherein the inner space of the at least one inner rotary drum is divided into multiple sections, and the at least one inner rotary drum includes: multiple baffles positioned along the inner periphery and along the whole length of the at least one inner rotary drum to enable free circulation of the raw material and movement from one end to the other; at least two first stiffeners diagonally positioned in between the multiple baffles and at a first section of

the at least one inner rotary drum; and at least two second stiffeners diagonally positioned in between the multiple baffles and at the multiple sections, wherein the multiple baffles, the at least two first stiffeners and the at least two second stiffeners break down the raw material while it passes from one end to another end of the at least one inner rotary drum.

[0061] A yet another aspect of the present invention provides a device for torrefying a raw material, comprising: a mixer-blender for semi-drying a raw material using waste heat by blending of the raw material with the waste heat into the mixer-blender; a feeding conveyor for receiving the waste heat and the semi-dried raw material from the mixer-blender to further reduce a moisture profile of the semi-dried raw material prior to feeding into the torrefaction device; and a biomass furnace for receiving balance waste heat from the mixer-blender and the feeding conveyor along with the further dried raw material to further reduce the moisture profile of the raw material prior to feeding into the torrefaction device, wherein the mixer-blender, the feeding conveyor and the biomass furnace pre-heats the raw material prior to feeding into the torrefaction device; at least one inner rotary drum which rotates and receives the pre-heated raw material for breaking down the raw material while passing from one end to another end of the at least one inner rotary drum; and at least one outer stationary drum surrounding the at least one inner rotary drum for allowing flow of heat into an annular space between the at least one inner rotary drum and at least one outer stationary drum for torrefying the pre-heated raw material into the at least one inner rotary drum.

[0062] An embodiment of the present invention provides the torrefaction method employs a parallel flow, wherein the wettest raw material comes in contact with the hottest gas as they enter the torrefaction device for rapid evaporation and rapid cooling of process heat.

[0063] Another embodiment of the present invention provides the torrefaction method employs a counter flow, wherein the wettest raw material is introduced into the at least one inner rotary drum on the opposite end of which the heat enters the torrefaction device and torrefied material discharges on the opposite end of the torrefaction device.

[0064] An embodiment of the present invention provides the torrefaction method is closed loop process wherein flue gases from the torrefaction device is redirected into the torrefaction device depending on their moisture level.

[0065] An embodiment of the present invention provides the at least one inner rotary drum is inclined at an angle of inclination to allow slow movement of the raw material from one end to an another.

[0066] Another embodiment of the present invention provides the at least one inner rotary drum has multiple roller tracks on its outer surface for helping in rotation.

[0067] Yet another embodiment of the present invention provides the at least one inner rotary drum further includes at a plurality of thermocouple sensors and a plurality of rotation sensors.

[0068] An embodiment of the present invention provides the device includes a control panel for controlling the mixer-blender, the feeding conveyor, the biomass furnace, the at least one inner rotary drum and the at least one outer stationary drum, wherein the control panel is equipped with variable frequency drive (VFD) for feed control; multiple thermocouple sensors; multiple rotation sensors; and an auto cut-off switch for temperature control.

BRIEF DESCRIPTION OF DRAWINGS

[0069] For a better understanding of the embodiments of the systems and methods described herein, and to show more clearly how they may be carried into effect, references will now be made, by way of example, to the accompanying drawings, wherein like reference numerals represent like elements/components throughout and wherein:

[0070] FIG. 1 illustrates an exemplary diagram of a perspective view showing a rotary drum reactor torrefaction device, according to an embodiment of the present invention;

[0071] FIG. 2 illustrates an exemplary diagram of a side view showing a rotary drum reactor torrefaction device, according to an embodiment of the present invention;

[0072] FIG. 3 illustrates an exemplary diagram of an internal rotary drum of the torrefaction device, showing baffles and stiffeners of the rotary drum, according to an embodiment of the present invention; and

[0073] FIG. 4 illustrates an exemplary diagram showing multiple sections or shells of the torrefaction device, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF INVENTION

[0074] This patent describes the subject matter for patenting with specificity to meet statutory requirements. However, the description itself is not intended to limit the scope of this patent. The principles described herein may be embodied in many different forms.

[0075] Illustrative embodiments of the invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

[0076] The present invention provides a rotary drum reactor torrefaction device for torrefying a biomass fuel. The torrefaction device is an oxidative indirect-fired rotary torrefyer, that is designed to produce torrefied fuel from locally available waste raw material such as Agri residues (Groundnut, rice husk, peanut, cotton stalk etc.), industrial waste such as dolochar, and even forest residues and invasive species such as *Juliflora*, *Lantana etc*.

[0077] The rotary drum or cylinder may be fed with an appropriate raw material, for example, the raw material may include and is not limited to a biomass or biomass pellets or agricultural waste or forest waste, such as like poplar, eucalyptus, saw dust, grass, hay,

sugarcane trash leaves and tops, paddy straw, Dried cashew nut shells, Groundnut shells, Maize stalk and cobs, Wheat straw, Rice straw, Soya stalk and husk, Cotton stalk, Jute sticks, Mustard stalk, Almond shell, Wood shavings, Wood chips and the like including even Municipal Solid Waste (MSW). Based on different geographical locations, the locally available agro-residue may be readily converted into torrefied biomass / torrefied pellets in the present torrefaction device. It may be appreciated by the person ordinarily skilled in the art that the torrefaction device may torrefy any type of biomass, or biological waste for producing a torrefied fuel, without departing from the meaning and scope of the present invention.

[0078] Depending on the design of the torrefaction device, the conveying of the raw material can be via a belt or a screw conveyor or a bucket elevator.

[0079] In an embodiment, the torrefaction device may be installed with wheels or may be attached to an automobile for providing mobility to the torrefaction device for on field torrefaction.

[0080] Referring to FIGs. 1-4, a torrefaction device 100 is a machine where raw material is subjected to conduction heating to remove moisture and some of the low volatiles. According to an embodiment, of the present invention, rotary drum reactor torrefaction device 100 may include a main twin drum torrefyer reactor that has at least one inner rotary drum and an outer stationary drum surrounding the inner rotary drum. The torrefaction device 100 also includes at least one or more of the following components:

[0081] 1. Furnace

[0082] 2. Raw Material

[0083] 3. Feeding Conveyor

[0084] 4. Inlet (102)

[0085] 5. Feeding Cover

[0086] 6. Roller Ring

[0087] 7. Carrier Roller

[0088] 8. Drum

[0089] 9. Transmission

[0090] 10. Gear Ring

[0091] 13. Discharge Cover

[0092] 14. Dust Collector

[0093] 15. Chimney

[0094] 16. Induced Draft Fan

[0095] 17. Motor

[0096] 18. Outlet

[0097] 19. Discharging Conveyor

[0098] 20. Feed belt with 3 HP motor to convey the raw material to torrefyer at desired speed based on the VFD controls in a control panel. In case the rotation of an inner drum stops, the feeding will automatically stop for safety.

[0099] 21. output jacketed water-cooled conveyor for transporting and simultaneously cooling the torrefied biomass into the storage silo/ receptacle with 3hp motor.

[00100] 23. Electrical panel

[00101] 24. Mini cooling tank cum tower with water pump with 2 HP motor.

[00102] 25. Suction blower for cleaning of the torrefyer at regular intervals.

[00103] 26. Laser gun for periodically checking the temperature inside a chamber.

[00104] 27. Hammer mill to bring the particle size within the specification to be used, the suitable hammer mill would be required. Once the material is torrefied, the grind ability improves significantly and the energy required is a fraction of what is required of grinding raw biomass (10-15% only). For e.g.: a two ton per hour hammer mill would require about 50 HP motor.

[00105] 28. Chimney- for natural draught, the chimney of appropriate height is included in the system.

[00106] A raw material in appropriate amount is fed to the torrefaction device 100, where the raw material is heated using conduction heating to remove moisture and some of the low volatiles. The torrefaction device 100 may have twin drums or cylinders: one rotating drum or cylinder 302 and a stationary drum or cylinder 202. The rotating cylinder 302 is fed with the raw material that needs to be torrefied. In an embodiment, the rotating cylinder 302, which is made of 6mm-thick MS plate, has a diameter of 1.2 m and

a length of 9.6 m rotating at a Variable speed. A driving motor assembly 204 including a driving motor rotates the rotating cylinder 302 and, in an embodiment, the drive with 10-HP gear motor (1:14) is used to rotate the rotating cylinder 302.

[00107] The rotating cylinder 302 is inclined at an angle of inclination to allow slow movement of the raw material from an inlet to an outlet end of the rotating cylinder 302. The angle of inclination is 2 degrees, according to an embodiment. Also, the rotating cylinder 302 has roller tracks 310 on its outer surface, helps in rotation of the rotating cylinder 302.

[00108] Inside the rotating cylinder 302, there are number of straight baffles 306, with a stiffener 304 (also 308) for each baffle 306, which lifts and stirs the raw material while passing from one end to the other end of the rotating cylinder 302. The baffles 306 are so positioned at different levels and tapered over the length of the rotating cylinder 302 to enable the free circulation of the raw material and movement from one end to the other. In an embodiment, the rotating cylinder 302 has around 260 pcs of 10 cm wide baffles 306, with 1-cm stiffener 304. In an embodiment, the stiffener 304 is positioned between the baffles 306 in a first section or shell (e.g., 402 in FIG. 4) of the rotating cylinder 302, whereas the stiffener 308 is positioned between the baffles 306 in the next second section or shell (e.g., 404 in FIG. 4) of the rotating cylinder 302, being rotated at 45 degrees.

[00109] The rotating cylinder 302 is heated by a hot flue gas from a biomass furnace. Flue gas enters and travels through an annular space between the rotating cylinder 302 and the stationary cylinder 202 and exits through a chimney located at the end section of the rotating cylinder 302. As the flue gases are at a usable temperature, the heat is recycled at multiple points, as a part of this technology used in the present invention, for efficient use of the waste heat. Flue gases travelling through the annular space between the rotating cylinder 302 and the stationary cylinder 202 indirectly heats the raw material conveyed inside the rotating cylinder 302.

[00110] The present invention implements a three-stage channelizing of heat that integrates the process and minimizes the stack release of the gases. The uniqueness of the

device 100 enables the torrefaction to take place with frugal energy in terms of electricity as also the fuel for firing the device 100 to generate the required temperature.

[00111] For implementing the three-stage channelizing of heat, the design of the device 100 incorporates a pre-bin wherein the waste heat is sent into a mixer-blender and while the blending of the raw material is taking place with the waste heat, the raw material is being semi-dried. The next stage is the transfer of the raw material into the torrefyer device 100 which is again via a jacketed feeding conveyer. The feeding conveyer feeds the raw material into the torrefaction device 100. In an embodiment, the feeding conveyer can be a jacketed screw conveyor, a belt, or a bucket elevator, individually or in combination.

[00112] After getting semi-dried in the first stage in the mixer blender, the waste heat is fed into the outer or jacketed chamber of the feeding conveyer to further reduce the moisture profile prior to feeding into the torrefaction device 100. The third stage of pre-heating takes place wherein the balance waste heat, that is remaining after first and second stages, is fed into the biomass furnace which is firing the heat into a reactor outer chamber of the torrefaction device 100. Thus, with this three-pronged or three-stage moisture reduction prior to firing into the torrefaction device 100 using the waste heat, the biomass consumption into the furnace, post the initial firing and reaching the temperature profile, becomes the fraction of the initial feed into the furnace. This highly efficient three-stage moisture reduction is the essence of the invention.

[00113] Heat is then transferred to the raw material by conduction heating in the rotating cylinder 302 where moisture and some volatile matters are removed.

[00114] In an embodiment, the heat source may include and is not limited to gas, diesel, coal, Wood, etc. In an embodiment, the present invention may use wood along with the waste heat for environmental and lower cost consideration.

[00115] In an embodiment, the torrefaction device 100 employs a parallel flow, which means the wettest raw material comes in contact with the hottest gas as they enter the torrefaction device 100. This results in a rapid evaporation and rapid cooling of the hot process gas. This typically allows the torrefyer shells (e.g., the shells 402, 404, 406,

408 in FIG. 4) to operate slightly cooler than the counter-flow configuration, which extends the life cycle and decreases maintenance of the torrefaction device 100.

[00116] At the input area, the hot surface is much higher than the raw material which leads a rapid heat exchange between the hot surface and the raw material, moisture becomes easy to evaporate. As explained above, the moisture reduction through the unique three-stage process of using waste heat enhances the ability to do this moisture reduction faster and most efficiently. This heat way is suitable for high moisture materials.

[00117] For the viscous materials, when it feeds into a torrefyer dryer, as the rapid water evaporates, the moisture goes down and helps to reduce the bonding rate, the easier-move material increases the torrefying efficiency.

[00118] The low negative pressure in the feeding place leads to low air leakage from the input, thus keeps the hot air in the torrefaction device 100 steadier with the temperature and the velocity.

[00119] In another embodiment, the torrefaction device 100 employs a counter flow, which means the wet material is introduced into the rotating cylinder 302 on the opposite end of which the hot gas enters the torrefaction device 100 and torrefyed material discharges on the opposite end of the torrefaction device 100 as the exhausting vapors.

[00120] The counter flow is suitable for raw material with low moisture and low heat sensitive. The drying rate is evenly distributed. So counter flow is more suitable for the raw material which is strict with the final moisture. As the heating air move from the dry end to the wet end, as the function of the wet air, there will be less dust in the exhaust.

[00121] The torrefaction device 100 employs the parallel or the counter flow of heating depending on the requirement of the final product.

[00122] The rotary drum or cylinder 302 of the torrefaction device 100 has higher capacity, continuous production; simple structure, easy on operating; low failure rate; low cost of maintenance. The rotary drum or cylinder 302 can be used to dry variety of the raw material even with high adhesion. The rotary drum or cylinder 302 has flexible

operation, the quality of final product won't be much changed when the capacity changes. Also, the rotary drum or cylinder 302 is easy to clean.

[00123] In an embodiment, the torrefaction device 100 for oxidative torrefaction has twin drums of boiler grade steel. Outer drum or cylinder 202 is for indirect heating. Internal drum or cylinder 302 rotates while the heat is passed into the outer drum cavity. The torrefaction device 100 is skid mounted for easy installation on a firm platform with anchor bolting.

[00124] The capacity of the torrefaction device 100 depends on the multiple factors such as input moisture, particle size, bulk density of the input material, desired output moisture level, surface area of the material, temperature profile, residence time, rotational velocity and so on. The capacity for lighter material like groundnut shells, the estimated capacity would be 2TPH. On heavier inputs such as juli flora waste, the capacity would be higher. Again, it is important to note that multiple variables determine the final capacity.

[00125] In an embodiment, the rotary drum or cylinder 302 has a diameter of 1.5 meters. and length of 12 meters, and outer drum 202 is insulated with aluminum cladding on top.

[00126] The rotary drum reactor 302 is fired with biomass-based furnace with additional option of pellet burner, if required. In case flue gases are available at the existing facility, 150-170 degree Celsius could be channelized for saving on the biomass operations. Further, the flue gases from the torrefaction device 100 can also be redirected into the torrefaction device 100 depending on their moisture level.

[00127] In an embodiment, the moisture of input should be below 12% with maximum of 20%. In case higher input moisture is there then pre-drying is necessary.

[00128] In an embodiment, the torrefaction device 100 may also include a touch screen PLC placed panel with interlocking of the feeding conveyer and output conveyor that brings out the torrefied raw material from the device 100. The panel is equipped with variable frequency drive (VFD) for feed control. There are thermocouple sensors at three points and rotation sensors at two points inside the reactor. Auto cut-off for temperature control is inbuilt.

[00129] The driving motor that is used to rotate the rotating cylinder 302 has a gear system with twin rollers driven by 10Hp motor is installed, according to an embodiment. The rotational velocity based on the gear ratio and the VFD control can be minimized at 0.5 rotations per minute which allows for flexibility in residence time. The torrefaction device 100 is placed at a certain angle to aid the flow of material and elevated at the starting point with a tapered decline over the length of the torrefaction device 100, as mentioned above.

[00130] Depending upon the raw material to be torrefied, the temperature ranges between 220-270 degree Celsius, according to an embodiment. This is the most critical aspect of torrefaction which is complemented by the ability to control the residence time and the rotational velocity.

[00131] The flue gas generated in the entire process of torrefaction is successfully recirculated as the design is a closed loop. As the flue gases are at a usable temperature, the heat is recycled at multiple points as a part of this invention for efficient use of the waste heat. The three-stage channelizing of heat integrates the process and minimizes the stack release of the gases. The uniqueness of the device 100 enables the torrefaction to take place with frugal energy in terms of electricity as also the fuel for firing the system to generate the required temperature.

[00132] Advantageously, torrefaction device 100 fits all the mandatory criteria of producing torrefied biomass, according to the government, with sufficiently high heating value, low moisture content and high moisture resistance as well as a high transport and energy density. The torrefaction equipment is capable of running continuously on 24h/7d basis without releasing volatile organic compound (VOC) as emissions. It has easy-to-operate process controls that requires only a small crew of operators and minimum maintenance. It further employs automated process controls in order to maintain temperatures within ranges fostering complete mild pyrolysis of the woody biomass. It is designed to facilitate a scale-up to higher capacity levels at a later date. In other words, the technology successfully caters to the need for the development of torrefied biofuels which is the need of the hour and has been considered as an important countermeasure to abate anthropogenic CO_2 emissions, suppress deteriorated atmospheric greenhouse

effect, and mitigate global warming at a cost and attendant efficiency which is unparalleled.

[00133] Numerous variations, whether explicitly given in the specification or not, such as differences in structure, dimension, and use of material, are possible. Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any component(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or component of any or all the claims.

[00134] It is intended that the disclosure and examples be considered as exemplary only. Though the present disclosure includes examples from torrefaction devices and methods, the system and method disclosed herein may be employed for various applications as would be appreciated by one skilled in the art. The references to measuring devices and machines used here are intended to be applied or extended to the larger scope and should not be construed as restricting the scope and practice of present invention.

I Claim

1- A torrefaction method, comprising:

(a) semi-drying a raw material using waste heat by blending of the raw material with the waste heat into a mixer-blender;

(b) feeding the waste heat and the semi-dried raw material from the mixer-blender in (a) into a feeding conveyor to further reduce a moisture profile of the semi-dried raw material prior to feeding into a torrefaction device;

(c) feeding balance waste heat from the mixer-blender in (a) and the feeding conveyor in (b) along with the further dried raw material in (b) into a biomass furnace to further reduce the moisture profile of the raw material prior to feeding into the torrefaction device; and

(d) conveying the raw material after pre-heating in (a), (b) and (c) into at least one inner rotary drum of the torrefaction device for breaking down the raw material while passing from one end to another end of the at least one inner rotary drum, and feeding heat in addition to the waste heat into an annular space between the at least one inner rotary drum and at least one outer stationary drum surrounding the at least one inner rotary drum of the torrefaction device for removing moisture and other volatile matters in the raw material in order to torrefy the raw material, wherein the at least one inner rotary drum rotates while the heat is passed into the annular space and the at least one outer stationary drum is stationary.

2- The method as claimed in claim 1, wherein the torrefaction method employs a parallel flow, wherein the wettest raw material comes in contact with the hottest gas as they enter the torrefaction device for rapid evaporation and rapid cooling of process heat.

3- The method as claimed in claim 1, wherein the torrefaction method employs a counter flow, wherein the wettest raw material is introduced into the at least one inner rotary drum on the opposite end of which the heat enters the torrefaction device and torrefied material discharges on the opposite end of the torrefaction device.

4- The method as claimed in claim 1, wherein the torrefaction method is closed loop process wherein flue gases from the torrefaction device is redirected into the torrefaction device depending on their moisture level.

5- A device for torrefying a raw material, comprising:

at least one inner rotary drum which rotates and receives pre-heated raw material for breaking down the raw material while passing from one end to another end of the at least one inner rotary drum; and

at least one outer stationary drum surrounding the at least one inner rotary drum for allowing flow of heat into an annular space between the at least one inner rotary drum and at least one outer stationary drum for torrefying the pre-heated raw material into the at least one inner rotary drum;

wherein the inner space of the at least one inner rotary drum is divided into multiple sections, and the at least one inner rotary drum includes:

multiple baffles positioned along the inner periphery and along the whole length of the at least one inner rotary drum to enable free circulation of the raw material and movement from one end to the other;

at least two first stiffeners diagonally positioned in between the multiple baffles and at a first section of the at least one inner rotary drum; and

at least two second stiffeners diagonally positioned in between the multiple baffles and at the multiple sections,

wherein the multiple baffles, the at least two first stiffeners and the at least two second stiffeners break down the raw material while it passes from one end to another end of the at least one inner rotary drum.

6- The device of claim 5 further comprises:

a mixer-blender for semi-drying a raw material using waste heat by blending of the raw material with the waste heat into the mixer-blender;

a feeding conveyor for receiving the waste heat and the semi-dried raw material from the mixer-blender to further reduce a moisture profile of the semi-dried raw material prior to feeding into the torrefaction device; and

a biomass furnace for receiving balance waste heat from the mixer-blender and the feeding conveyor along with the further dried raw material to further reduce the moisture profile of the raw material prior to feeding into the torrefaction device;

wherein the mixer-blender, the feeding conveyor and the biomass furnace pre-heats the raw material prior to feeding into the torrefaction device.

7- The device of claim 6, wherein the at least one inner rotary drum is inclined at an angle of inclination to allow slow movement of the raw material from one end to an another.

8- The device of claim 5, wherein the at least one inner rotary drum has multiple roller tracks on its outer surface for helping in rotation.

9- The device of claim 6, wherein the at least one inner rotary drum further includes at a plurality of thermocouple sensors and a plurality of rotation sensors.

10- A device for torrefying a raw material, comprising:

a mixer-blender for semi-drying a raw material using waste heat by blending of the raw material with the waste heat into the mixer-blender;

a feeding conveyor for receiving the waste heat and the semi-dried raw material from the mixer-blender to further reduce a moisture profile of the semi-dried raw material prior to feeding into the torrefaction device; and

a biomass furnace for receiving balance waste heat from the mixer-blender and the feeding conveyor along with the further dried raw material to further reduce the moisture profile of the raw material prior to feeding into the torrefaction device, wherein the mixer-blender, the feeding conveyor and the biomass furnace pre-heats the raw material prior to feeding into the torrefaction device;

at least one inner rotary drum which rotates and receives the pre-heated raw material for breaking down the raw material while passing from one end to another end of the at least one inner rotary drum; and

at least one outer stationary drum surrounding the at least one inner rotary drum for allowing flow of heat into an annular space between the at least one inner rotary drum and at least one outer stationary drum for torrefying the pre-heated raw material into the at least one inner rotary drum.

11- The device of claim 10, wherein the inner space of the at least one inner rotary drum is divided into multiple sections, and the at least one inner rotary drum includes:

multiple baffles positioned along the inner periphery and along the whole length of the at least one inner rotary drum to enable free circulation of the raw material and movement from one end to the other;

at least two first stiffeners diagonally positioned in between the multiple baffles and at a first section of the at least one inner rotary drum; and

at least two second stiffeners diagonally positioned in between the multiple baffles and at the multiple sections,

wherein the multiple baffles, the at least two first stiffeners and the at least two second stiffeners break down the raw material while it passes from one end to another end of the at least one inner rotary drum.

12- The device of claim 11 further includes:

a control panel for controlling the mixer-blender, the feeding conveyor, the biomass furnace, the at least one inner rotary drum and the

at least one outer stationary drum, wherein the control panel is equipped with variable frequency drive (VFD) for feed control;

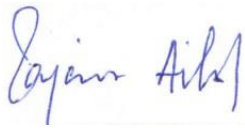
multiple thermocouple sensors;

multiple rotation sensors; and

an auto cut-off switch for temperature control.

Dated this 31 day of March, 2022

SUKHDEEP SINGH RANA
By their attorney



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ABSTRACT

A ROTARY TORREFACTION DEVICE

Embodiments of the present invention provide a device for torrefaction of a raw material, such as a biomass. The device includes a rotating cylinder with a number of baffles and stiffener to rotate and stir the raw material. The device employs a unique three-stage channelizing of heat that integrates the torrefaction process and minimizes the stack release of the gases. Also, the device employs a parallel flow and counter flow of heat with respect to the raw material, depending on what is the final product required.

Fig. 1