A system for recycling carbon-containing material is provided. The system includes a reactor for heating the carbon-containing material to produce carbon-containing gases. The system further includes a condenser operably connected to the reactor for condensing a portion of the carbon-containing gases to provide condensed gas and non-condensed gas. The system further includes a conduit arrangement operably connected to the reactor and the condenser wherein the non-condensed gas from the condenser is returned to the reactor.
PROCESS AND SYSTEM FOR DECOMPOSITION OF CARBON CONTAINING WASTE AND PROCESS AND SYSTEM FOR RECYCLING CARBON CONTAINING WASTE

CROSS-REFERENCE TO RELATED APPLICATION

0001 This application claims benefit of U.S. Provisional Patent Application No. 61/669,386, entitled "PROCESS AND SYSTEM FOR DECOMPOSITION OF CARBON CONTAINING WASTE AND PROCESS AND SYSTEM FOR RECYCLING CARBON CONTAINING WASTE," filed Jul. 9, 2012, the disclosure of which is incorporated by reference in its entirety.

TECHNICAL FIELD

0002 The present disclosure relates generally to a process and system for the decomposition and recycling of waste, and more particularly to a process and system for the decomposition and recycling of carbon-containing waste, such as vehicle tires and plastic.

BACKGROUND

0003 Carbon-containing materials, such as rubber and plastics, form a major portion of all waste. The disposal of carbon-containing materials has been a long-standing environmental problem. Incinerating carbon-containing waste leads to serious environmental pollution. Dumping carbon-containing waste into landfills is also not a feasible long term solution. Furthermore, the recycling of these materials can be costly and difficult because of inadequate separation prior to recycling.

0004 Therefore, there is considerable interest in developing a process for the treatment of waste plastic. One approach has been to use pyrolysis to recover the basis chemicals and fuels from the carbon-containing materials. In pyrolysis the carbon-containing materials are heated in the absence of oxygen in a closed environment, with the resulting products of pyrolysis available for use as a chemical feedstock, or fuel. This process ultimately reduces the costs of monomers and the consumption of petroleum.

0005 Although pyrolysis is an attractive alternative to plastics landfiling or incineration, there are challenges associated with the pyrolysis of carbon-containing materials. Therefore, it would be advantageous to have an improved system and process for recycling carbon-containing materials that is more efficient, has reduced decomposition time, and uses ecologically clean technology.

SUMMARY

0006 In accordance with an embodiment of the present disclosure, a system for recycling carbon-containing material is provided. The system includes a reactor for heating the carbon-containing material to produce carbon-containing gases. The system further includes a condenser operably connected to the reactor for condensing a portion of the carbon-containing gases to provide condensed gas and non-condensed gas. The system further includes a conduit arrangement operably connected to the reactor and the condenser wherein the non-condensed gas from the condenser is returned to the reactor.

0007 In accordance with an embodiment of the present disclosure, a method for recycling carbon-containing material is provided. The method includes preheating carbon-containing material, charging the pre-heated carbon-containing material to a reactor, and heating the carbon-containing material in the reactor to form carbon-containing gases. The method further includes condensing a portion of the carbon-containing gases to form condensed gas and non-condensed gas and introducing the non-condensed gas to reactor as coolant.

0008 Additional features, advantages, and embodiments of the disclosure may be set forth or apparent from consideration of the following detailed description, drawings, and claims. Moreover, it is to be understood that both the foregoing summary of the disclosure and the following detailed description are exemplary and intended to provide further explanation without limiting the scope of the disclosure as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

0009 The accompanying drawings, which are included to provide a further understanding of the disclosure, are incorporated in and constitute a part of this specification, illustrate embodiments of the disclosure and together with the detailed description serve to explain the principles of the disclosure. No attempt is made to show structural details of the disclosure in more detail than may be necessary for a fundamental understanding of the disclosure and the various ways in which it may be practiced. In the drawings:

0010 FIG. 1 shows a schematic of a system for recycling carbon-containing waste according to an embodiment of the present disclosure.

0011 FIG. 2 shows a process flow diagram of a process for recycling carbon-containing waste according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

0012 The embodiments of the disclosure and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments and examples that are described and/or illustrated in the accompanying drawings and detailed in the following description. It should be noted that the features illustrated in the drawings are not necessarily drawn to scale, and features of one embodiment may be employed with other embodiments as the skilled artisan would recognize, even if not explicitly stated herein. Descriptions of well-known components and processing techniques may be omitted so as to not unnecessarily obscure the embodiments of the disclosure. The examples used herein are intended merely to facilitate an understanding of ways in which the disclosure may be practiced and to further enable those of skill in the art to practice the embodiments of the disclosure. Accordingly, the examples and embodiments herein should not be construed as limiting the scope of the disclosure, which is defined solely by the appended claims and applicable law. Moreover, it is noted that like reference numerals represent similar parts throughout the several views of the drawings.

0013 FIG. 1 shows a schematic of a system for recycling carbon-containing waste according to an embodiment of the present disclosure. More specifically, FIG. 1 shows a system for the thermal decomposition of carbon-containing waste in a temperature range of 465-585 degrees Celsius, with a con-
tinuous supply of heat, hermetically sealed loading of waste and unloading of solid residue, in a two-stage heating system with continuous pumping out of gases in vacuum.

[0014] Carbon-containing waste can be found in three aggregative states: solid, liquid and gas. Solid waste from industrial production and daily life includes mainly high-molecular polymers and mineral components; liquid waste includes suspension-emulsion mixtures of liquid hydrocarbons that may include olefinic, alkyl-aromatic and oligomeric compounds; gaseous waste includes primarily methane, ethane, propane, butane and their derivatives. All of the above-mentioned types of waste can be recycled using the method disclosed herein with subsequent capture of waste decomposition products.

[0015] The composition of carbon-containing waste may include: waste rubber products (used tires, rubber hoses, etc.), waste plastics (bottles PET, etc.), organic waste of animal and vegetable origin, medical waste (single-use syringes, medical gloves, surgical waste, etc.) and other types of waste. For completeness of waste decomposition, reduction of waste decomposition and the maximum productivity of the installation, it is recommended that waste is prepared by being reduced to a size not exceeding 200×200 mm.

[0016] In the first stage, the carbon-containing waste is heated at temperatures in the range of 250-465 degrees Celsius. This first stage heating may occur in a preheating chamber for carbon-containing waste in the reactor. During this first stage, links between low-molecular compounds rupture resulting in the formation of radicals, which are saturated by hydrogen to a state at the limit of obtaining combustible gases (methane, ethane, propane) and may be pumped out at low concentration into a condensation and purification systems. The purification and condensation systems are explained in further detail below.

[0017] Once heated to a temperature of 465 degrees Celsius, the carbon-containing waste enters the second-stage in a reactor chamber where the waste is heated to a temperature of 465-585 degrees Celsius. The high-molecular hydrocarbons may be decomposed at these temperatures with the rupture of polymer chains and the formation of radicals, which in turn react with the released hydrogen to produce hydrocarbons of olefinic, aromatic, and oligomeric series of molecular compounds.

[0018] Gaseous and vaporous compounds may be removed by vacuum into the condensation and purification system. Vaporous compounds may be condensed to a liquid state. The resulting liquid is generally a mixture of alkyl-aromatic and oligomeric hydrocarbon compounds (from 68 to 85% mass) with a high octane number, which can serve as feedstock for further waste processing or high-calorie fuel. The presence of a sufficiently large amount of sulfur (up to 0.87%) may require, if necessary, a process of desulfurization.

[0019] The process of decomposition at temperatures of 465-585 degrees Celsius is optimal, since the process of obtaining highly toxic compounds, oxins and dioxins occurs mainly at higher temperatures. Coke-like solid residue may include low-grade carbon black and mineral components.

[0020] The main difference between the method of the present disclosure and other known methods, is that a coolant (heat) may be heated in a separate unit and may be fed separately into the heating zones of the reactor. The leak-proof arrangement of the process may be ensured by a special hardware design of the reactor and a weak concentration in the reactor, which allows the removal of gaseous and vaporous products of decomposition of carbon-containing waste.

[0021] The removal of gaseous and vaporous products from the second stage of the reactor allows the process to be substantially carried out. Gas purified from the vaporous components may be used either as fuel for the production of the coolant (heat), or for commercial purposes. After burning the gas, the gas is effectively turned into air with a mass fraction of organic compounds of not more than 0.8% by volume, and carbon monoxide of no more than 0.1% by volume, which is environmentally safe for human activity.

[0022] Referring now to FIG. 1, a system 10 for recycling carbon-containing waste is shown. The recycling system 10 includes a carbon-containing feedstock delivery system 15. As shown in FIG. 1, the delivery system may be a truck, which is used to deliver the carbon-containing feedstock via a truck. The recycling system 10 may also include a grinder 20 which may be used to shred the carbon-containing waste prior to processing the waste. Using a grinder 20 is particularly useful when handling large solid carbon-containing waste such as tires. In one embodiment according to the present disclosure, the waste is shredded to a size not exceeding 200×200 mm.

[0023] The recycling system 10 further includes a reactor delivery system 25, reactor unloading system 30, reactor 35 and a reactor loading system 40. The reactor delivery system 25 may be used to deliver the carbon-containing waste from the grinder to the reactor 35. The reactor delivery system 25 may be, for example, a conveyor system that transports the waste to the top of the reactor 35. The reactor loading system 40 may work in conjunction with the reactor unloading system 30 to ensure that the volume of the reactor 35 is not exceeded and that the reactor 35 remains sealed such that the pyrolysis operation is not sacrificed. Both the reactor unloading system 30 and the reactor loading system 40 may be for example hoppers.

[0024] The reactor 35 may comprise any unit or number of units suitable for pyrolysis of carbon-containing materials. For example, the reactor 35 may be a two-stage reactor as described herein. Alternatively, the reactor 35 may be single-stage or multi-stage. A person skilled in the art will recognize that the reactor 35 must be at least a two-stage reactor to facilitate a continuous process according to the present disclosure whereas a single stage reactor will operate in a batch manner.

[0025] As shown in FIG. 1, a separation unit 38 may be positioned downstream from the reactor 35 in some embodiments according to the present disclosure. The separation unit 38 may be used to separate carbon from metal wires. A separation unit 38 is particularly useful if the carbon-containing waste includes discarded vehicle tires that have metal wires incorporated in them. There may also be carbon collection tank 42 and a metal wire collection tank 43. Both collection tanks 42, 43 may be connected to the separation unit 38. The carbon collection tank 42 is designed to collect a large fraction of unwanted carbon, such as slag, from the reactor 35.

[0026] The recycling system 10 may also include a control system for reactor heating 45 and a heating unit 50, which may be used to heat the reactor 35 such that the carbon-containing waste undergoes pyrolysis. The control system 45 operates to control the temperature within the range of 265-585 degrees Celsius. As described herein, keeping the temperature within this temperature range will minimize the formation of certain toxins. The recycling system 50 may also
include a filtration system 55 for the exhaust gases. The recycling system 10 may also include a heating unit ignition chimney 60.

[0027] The recycling system 10 may also include a gas purification system 65 for purifying the effluent gas from the reactor 35 as shown in FIG. 1. The gas travels through the gas purification system 65 prior to entering the condenser 70. As shown in FIG. 1, a small fraction of the carbon may be unloaded directly from the gas purification cycle 65.

[0028] The recycling system 10 may also include a condenser 70 that is downstream from the purification system 65. A cooling tower 72 and circulation pump 74 may also be used to supply cooling water to the condenser 70. The condenser 70 condenses a portion of the purified gas to a condensed gas. These carbon-containing condensed gases may then be further processed to provide usable end products such as liquid heating fuel. As shown in FIG. 1, the condensed gases may be pumped from the condenser 70 using a condensation pump 76 and offloaded for use. The offloading may occur using a truck.

[0029] The non-condensed gases may also exit the condenser 70 and enter a smoke exhaust 80 and a gas distribution unit 85. A portion of the non-condensed gases may be used to power a gas electric generator 90. The generator shown in FIG. 1 may be used to provide electricity to household consumers 95. The remaining portion of non-condensed gases may be used as coolant for the reactor 70. Therefore, the condenser 70 may be configured in some embodiments to divert a portion of the non-condensed gas from the condenser 70 to the reactor to be used as coolant. In FIG. 1, conduit is arranged from gas distribution unit 85 to heating unit 50 and the coolant is added directly into the reactor 35.

[0030] The constituents of this coolant gas are nitrogen, carbon dioxide and carbon monoxide. The process disclosed herein is more efficient and environmentally safe because the source of the coolant used is the effluent gas from the reactor. The coolant is not a byproduct of the decomposition process itself. The process of managing the coolant supply is automatically controlled by the temperature in the heat zones of the reactor 35.

[0031] The coolant may be fed into zones of the reactor 35 through separate conduits directly in the heating zones of the reaction mass. The spent coolant is removed together with the decomposition products in condensation and the cleaning of the dust-gas mixture.

[0032] FIG. 2 shows a flowchart of a process for recycling carbon-containing waste according to the principles of the disclosure. FIG. 2 more specifically shows an installation for recycling carbon-containing waste. The installation may be configured for capacities of 5 tons per day and above, subject to incremental increases. Other capacities are contemplated as well.

[0033] Referring now to FIG. 2, the first step in the process is preparing the carbon-containing waste. The preparation step may depend in part on the type of carbon-containing waste that is used in the process. For example, grinders and shredders may be used if the waste contains solid carbon-containing waste, in particular vehicle tires. Next, the carbon-containing waste is loaded into the reactor and heating of the carbon-containing waste is conducted. The heating step occurs in two stages (first stage and second stage) as discussed above.

[0034] After the carbon-containing waste is sufficiently heated and pyrolysis occurs, the carbon-containing waste from the reactor is purified and condensed. Solid residue is unloaded from the reactor at this time. Dust is also collected from the reactor and the carbon-water slurry is collected.

[0035] The resin from the purification system and condenser is separated. After separation, the carbon-containing waste is further purified and condensed. At this point, the liquid fraction is collected and used as the end product, usually heating fuel. The remaining carbon fraction is further purified and condensed. The next step is suction of the vapor gas mixture and separating the gas from the liquid. The gas is then heated and returned to the reactor as coolant by way of the heating unit.

[0036] The installation for this may include the following unit operations:

[0037] Unit for preparation of waste (shredder of waste, set of baskets, tank elevator, and the like);

[0038] Heating unit 50;

[0039] Unit for loading waste into the reactor 40;

[0040] Two-stage reactor 35;

[0041] Unit for unloading of the solid residue 30;

[0042] Dust collection system;

[0043] System for purifying and condensing the vapor-gas mixture 65, 70;

[0044] Resin separation system;

[0045] System for suction of vapor-gas and dust fractions out of the reactor;

[0046] Gas separation system;

[0047] System for collecting the carbon-water slurry;

[0048] System for collecting the liquid fraction;

[0049] Water circulation system;

[0050] Gas waste system;

[0051] System of sliding transitions;

[0052] Hydraulic process control system; and/or

[0053] Electrical and electronic process control system.

[0054] In this embodiment, prepared waste may enter the loading unit 40 through the skip hoist, and then be loaded into the reactor 35. The heating temperature may be regulated by a quantity of incoming coolant. The resultant vapor-gas fraction may be removed by vacuum, the solid fraction may be removed in the unloading unit. The vapor-gas mixture may pass through the system for purification and condensation 65, 70, as well as the resin separation system, where the condensed liquid fraction may enter the tank through a collecting system. The gas fraction, through the gas separation system, maybe fed to fuel burners of a heating unit, and for other needs (if necessary). The process control system for decomposition of waste in the installation may be electronic through electrical and hydraulic control stop valves.

[0055] The invention may be implemented in any type of computing devices, such as, e.g., a desktop computer, personal computer, a laptop/mobile computer, a personal data assistant (PDA), a mobile phone, a tablet computer, cloud computing device, and the like, with wired/wireless communications capabilities via the communication channels.

[0056] Further in accordance with various embodiments of the invention, the methods described herein are intended for operation with dedicated hardware implementations including, but not limited to, PCs, PDAs, semiconductors, application specific integrated circuits (ASIC), programmable logic arrays, cloud computing devices, and other hardware devices constructed to implement the methods described herein.

[0057] While the disclosure has been described in terms of exemplary embodiments, those skilled in the art will recognize that the disclosure can be practiced with modifications in the spirit and scope of the appended claims. These examples
given above are merely illustrative and are not meant to be an exhaustive list of all possible designs, embodiments, applications or modifications of the disclosure.

What is claimed is:

1. A system for recycling carbon-containing material comprising:
a reactor for heating the carbon-containing material to produce carbon-containing gases;
a condenser operably connected to the reactor for condensing a portion of the carbon-containing gases to provide condensed gas and non-condensed gas; and
a conduit arrangement operably connected to the reactor and the condenser wherein the non-condensed gas from the condenser is returned to the reactor.

2. The system of claim 1, further comprising a purification system operably connected to the reactor and the condenser wherein the carbon-containing gas enters the purification system after the reactor and before the condenser.

3. The system of claim 1, further comprising a grinder operably connected to the reactor.

4. The system of claim 1, wherein the carbon-containing material comprises shredded vehicle tires with dimensions not exceeding 200x200 mm.

5. The system of claim 1, wherein the reactor is a two-stage reactor or multi-stage reactor.

6. The system of claim 1, wherein the temperature of the reactor is from about 465 to about 585 degrees Celsius.

7. The system of claim 1, further comprising a gas electric generator wherein a portion of the non-condensed gases may be used to power a gas electric generator.

8. The system of claim 1, wherein the condensed gas is offloaded from the system and used as heating fuel.

9. The system of claim 1, wherein the non-condensed gas is coolant added to the reactor.

10. The system of claim 1, wherein the operation of the reactor is continuous.

11. A method for recycling carbon-containing material comprising the steps of:
preheating carbon-containing material;
charging pre-heated carbon-containing material to a reactor;
heating carbon-containing material in the reactor to form carbon-containing gases; condensing a portion of the carbon-containing gases to form condensed gas and non-condensed gas; and introducing the non-condensed gas to reactor as coolant.

12. The method of claim 11, wherein the preheating step occurs from about 250 to about 465 degrees Celsius.

13. The method of claim 11, wherein the heating step occurs from about 465 to about 585 degrees Celsius.

14. The method of claim 11, further comprising the step of grinding the carbon-containing material prior to the charging step.

15. The method of claim 11, further comprising the step of purifying the carbon-containing gas prior to the condensing step.

16. The method of claim 11, further comprising the step of offloading the condensed gas to be used as heating fuel.