CONTINUOUS STEAM PYROLYSIS APPARATUS AND PYROLYSIS FURNACE THEREFORE

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ABSTRACT
A continuous steam pyrolysis device and a pyrolysis furnace therefor are provided. The device comprises a heat generator, a combustion chamber and a superheated steam generator. The combustion chamber comprises a reaction chamber with a charge opening and a discharge opening, and one or more axial transporting structures installed in the reaction chamber, wherein each transporting structure has a central axis and comprises one or more proceeding zones and one or more blending zones. The total length of the blending zones along the central axis direction ranges from about 5% to about 35% of the length of the transporting structure.
FIG. 5

FIG. 6
CONTINUOUS STEAM PYROLYSIS APPARATUS AND PYROLYSIS FURNACE THEREFOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Taiwan Patent Application No. 097112500 filed on 7 Apr. 2008, the contents of which are incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a continuous steam pyrolysis apparatus, and more particularly, relates to a continuous steam pyrolysis apparatus having a unique transporting structure, which is especially used for the treatment of waste tires.

[0004] 2. Descriptions of the Related Art

[0005] Waste tires are generally recycled in two methods. The first method is the physical processing method, in which the waste tires are broken up, then the steel wires, nylon and rubber are separated, and finally the rubber is recycled in a form of raw rubber. However, as a recycled material, the recycled rubber has poor quality and is inappropriate for use as a raw material to produce tires. The recycled rubber thus obtained has a low resource utilization factor and is less economical. The other processing method incorporates a chemical process, in which the waste tires are broken up after adding an appropriate percentage of catalyst. The waste tires are then pyrolyzed at an appropriate temperature and an appropriate pressure to produce gaseous products, blended oils, carbon black, residuals and the like. Then, with an appropriate separating process such as the fractionating process, the byproducts with high economical value such as light oil, gasoline, kerosene, diesel oil and heavy oil may be separated from the blended oils. Recycling waste tires are, thus, more efficient.

[0006] It can be seen from the above description that the pyrolysis method for processing waste tires delivers a substantially better recycling economical benefit. Therefore, most of the related development efforts under way at present are directed to such a method. Conventional waste tire pyrolysis technologies may further be divided into two categories, namely, pyrolysis-in-batch technologies and continuous pyrolysis technologies. For the pyrolysis-in-batch technologies, waste tires are placed into a pyrolysis furnace which is then heated to activate a pyrolysis reaction. After completing the pyrolysis reaction, the processing procedures such as cooling and depressurization are conducted and pyro-products are taken out. Thereafter, another batch of waste tires can be placed into the furnace for processing. This approach is disadvantageous in that the pyrolysis furnace must be subjected to a heating/cooling cycle for each batch and the pyrolysis reaction has to be interrupted between the individual batches, resulting in a limited processing speed and a low production throughput. Furthermore, after processing each batch, the pyrolysis furnace has to be opened to take out the reaction products before the next batch of materials to be pyrolyzed can be loaded. This makes it difficult to effectively use gases that result from the pyrolysis reaction, and tends to cause the escaping of dusts and pyro-gases. Nowadays, waste tires are mostly processed through the continuous pyrolysis method to save time and costs, increase the production throughput and decrease hazard to the environment.

[0007] Continuous pyrolysis apparatuses commonly used at present can be divided into two categories: continuous pyrolysis-in-batch apparatuses and continuous pyrolysis apparatuses. A continuous pyrolysis-in-batch apparatus is disclosed in Taiwan Patent Publication No. 366304. This continuous pyrolysis-in-batch apparatus uses a plurality of pyrolysis furnaces in parallel, wherein each of them is controlled independently from each other, so that these parallel pyrolysis furnaces may be operated in sequence to accomplish a continuous pyrolysis. That is, when the pyrolysis reaction carried out in each pyrolysis furnace is completed, the pyrolysis furnace is cooled down independently, and then the pyro-products are withdrawn and a next batch is loaded. However, even though the pyrolysis reaction can be performed continuously according to such a continuous pyrolysis-in-batch apparatus, each of the furnaces is still subjected to repeated heating and cooling, as well as the loading and unloading of batches. Furthermore, the individual operation of each furnace makes the operation of the continuous pyrolysis-in-batch apparatus more complex. Moreover, such a continuous pyrolysis apparatus that uses a plurality of pyrolysis furnaces is necessarily huge and bulky in volume, and consequently limits its use in application.

[0008] Accordingly, continuous pyrolysis furnaces that do not require a plurality of parallel pyrolysis furnaces have been developed recently. For example, a continuous pyrolysis apparatus comprising a vertically arranged stirrer is disclosed in Taiwan Patent Publication No. 361356. The stirrer has a stirring rod and an auger conveyor disposed thereon to assist in stirring, preheating, pyrolyzing the waste rubber and preventing occurrence of the bridging phenomenon. However, this pyrolysis apparatus still adopts a dry pyrolysis method which uses a dry gas, such as an inert gas, to carry the resultant pyro-gas out. When using a dry pyrolysis method, the pyrolysis furnace may explode due to a significant amount of combustible oil gases generated during the pyrolysis which is conducted at high temperature. Moreover, sulfurous component(s) contained in waste tires will be released during the pyrolysis of the waste tires. For a conventional pyrolysis technology using an inert gas as the carrier gas, the gaseous sulfurous component(s) will lead to a high sulfur content in the resultant pyro-products according to Henry's Law, and the quality of the products is thereby lowered.

[0009] In view of the disadvantages of conventional pyrolysis apparatuses, a pyrolysis apparatus is provided in the present invention, which allows for continuous pyrolysis without increasing the number of pyrolysis furnaces and can prevent blocking and bridging phenomena in the pyrolysis furnace. Furthermore, the pyrolysis apparatus of the present invention allows for a continuous pyrolysis reaction, belonging to a continuous pyrolysis method, and eliminates the complex operational procedures of heating up and cooling down the pyrolysis apparatus. Additionally, the use of steam in the apparatus of the present invention can reduce the likelihood of explosion caused by combustible oil gases generated in the pyrolysis furnace, reduce the potential risks of the pyrolysis apparatus, and effectively dissolve the sulfurous component(s) into the steam and then carry the sulfurous component(s) out with the steam to reduce the sulfur content in the reaction products and the potential pollution extent on the environment.

SUMMARY OF THE INVENTION

[0010] One objective of this invention is to provide a pyrolysis furnace, which comprises a reaction chamber and
one or more axial transporting structures. The reaction chamber comprises a charge opening and a discharge opening, and the one or more axial transporting structures are installed in the reaction chamber. Each of the transporting structures has a central axis, and comprises one or more spiral segments and one or more paddle segments. The total length of the paddle segments along the central axis direction ranges from about 5% to about 35% of the length of the transporting structure. This pyrolysis furnace can be applied to a continuous steam pyrolysis apparatus to conduct a pyrolysis reaction therein, and is especially suitable for recycling waste tires through the pyrolysis process.

[0011] Another objective of this invention is to provide a continuous steam pyrolysis apparatus, which comprises a heat generator, a combustion chamber, and a superheated steam generator. The combustion chamber communicates with the heat generator and has a reaction chamber with one or more axial transporting structures disposed therein. The reaction chamber comprises a charge opening and a discharge opening. The one or more axial transporting structures are installed in the reaction chamber. In addition, the superheated steam generator communicates with the reaction chamber. Each of the transporting structures has a central axis and comprises one or more proceeding zones and one or more blending zones. The total length of the blending zones along the central axis direction ranges from about 5% to about 35% of the length of the transporting structure.

[0012] The detailed technology and preferred embodiments implemented for the subject invention are described in the following paragraphs accompanying the appended drawings for people with ordinary skill in this field to well appreciate the features of the claimed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a side view of an embodiment of a pyrolysis furnace of the present invention;
[0014] FIG. 2 is a cross-sectional view of an embodiment of a pyrolysis furnace of the present invention;
[0015] FIG. 3 is a partial enlarged view of the pyrolysis furnace of FIG. 2;
[0016] FIG. 4 is a schematic view of a continuous steam pyrolysis apparatus of this invention;
[0017] FIG. 5 is a side view of a superheated steam generator and a pyrolysis furnace in a continuous steam pyrolysis apparatus of the present invention; and
[0018] FIG. 6 is a schematic partial view illustrating how materials pass through a pyrolysis furnace of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] The pyrolysis furnace of the present invention comprises a reaction chamber with a charge opening and a discharge opening, and one or more axial transporting structures installed in the reaction chamber. Each of the transporting structures has a central axis, and comprises a plurality of spiral structures and a plurality of paddle structure disposed along the central axis direction. Accordingly, one or more spiral segments consisting of the screw structures and one or more paddle segments consisting of the paddle structures are formed. Each of the spiral/paddle structures has the same or different spacing from neighboring spiral/paddle structures. Preferably, each of the paddle segments is substantially identical in length, and each of the spiral segments is substantially identical in length. In an embodiment, each of the transporting structures comprises a plurality of spiral segments and a plurality of paddle segments that are alternately arranged with each other.

[0020] The reaction chamber of the pyrolysis furnace is preferably a tubular reactor, although it is not solely limited thereto. The so-called “tubular reactor” generally refers to any appropriate reactors in which a space for containing materials therein is formed into a striped shape, like a tube. Hence, the materials that are fed into the reaction chamber via the charge opening will proceed through the transporting structures of the reaction chamber along the central axis thereof while reacting in the reaction chamber, and finally move out of the reaction chamber via the discharge opening.

[0021] Because the transporting structure of the pyrolysis furnace of the present invention comprises paddle segments, the material to be pyrolyzed is stirred and blended in the paddle segments when transported along the central axis of the transporting structure to make the pyrolysis of the material in the reaction chamber more homogeneous and complete. It has been found that for the application of pyrolyzing waste tires, a too low proportion of the paddle segments makes it unable to achieve a desired stirring and blending effect. On the other hand, a too large proportion of the paddle segments makes the reaction chamber to be blocked by twisted steel wires in the waste tires. For this reason, the total length of the paddle segments along the central axis direction is typically controlled to range from about 5% to about 35% of the length of the transporting structure. Preferably, the total length of the paddle segments along the central axis direction ranges from about 10% to about 30% of the length of the transporting structure.

[0022] The transporting structure may be driven by any appropriate driving means (e.g., an electric motor), while the rotational speed of the screws of the transporting structure can be adjusted depending on the needs (e.g., species, composition and size of the material to be pyrolyzed) to control the resident time of the material to be pyrolyzed in the reactor chamber.

[0023] Optionally, the reaction chamber may comprise a plurality of reaction regions each comprising one transporting structure described above and in communication with each other, so that the material to be pyrolyzed can be transported among the reaction regions. These reaction regions “communicate” with each other in any appropriate forms. For example, the reaction regions may communicate with each other through a pipeline, or may be disposed adjacent to each other and communicate merely through the openings. The arrangement of the plurality of reaction chambers can keep any single transporting structure from overload while still achieving complete pyrolysis. Alternatively, the reaction regions may be arranged one above the other to make full use of the available space.

[0024] The present invention further provides a continuous steam pyrolysis apparatus, which comprises a heat generator, a combustion chamber, and a superheated steam generator.

[0025] The heat generator is adapted to supply necessary heat for the continuous steam pyrolysis apparatus. In one embodiment of this invention, the heat is supplied in the form of a high-temperature gas, which is obtained by combusting combustible gases recycled from the pyrolysis process or fuel oil through the appropriate equipment such as combustion furnaces. Preferably, the heat generator is capable of utilizing
the combustible gases recycled from the pyrolysis process to conserve energy and save the running cost.

[0026] The combustion chamber communicates with the heat generator to receive heat supplied by the heat generator to perform a pyrolysis reaction therein. The combustion chamber comprises a reaction chamber and an axial transporting structure located in the reaction chamber. In one embodiment, an appropriate pipeline is used to introduce heat generated by the heat generator into the combustion chamber to attain the necessary temperature for the pyrolysis reaction in the reaction chamber. The material to be pyrolyzed in the reaction chamber proceeds progressively and are timely stirred and blended via the axial transporting structure to achieve a uniform pyrolysis effect.

[0027] In conventional pyrolysis-in-batch techniques, products resulting from the pyrolysis reaction must be taken out with additional manpower or through machine operations, which is both time- and labor-consuming. Moreover, because there is no effective means to properly stir the material under reaction, conventional pyrolysis-in-batch apparatuses often fail to achieve a uniform and complete pyrolysis effect. In contrast with conventional pyrolysis-in-batch apparatuses, the axial transporting structure disposed in the reaction chamber of the pyrolysis apparatus of the present invention comprises proceeding zones for moving the material to be pyrolyzed forward during the reaction and also blending zones for appropriately stirring the material to be pyrolyzed while the material is moved forward, thereby the material to be pyrolyzed being mixed more uniformly and pyrolyzed more completely. Furthermore, with the transporting structure arranged in the reaction chamber, the pyro-products can be transported out of the reaction chamber for subsequent processing, thus remarkably improving the performance of the apparatus and the economical benefits.

[0028] In an embodiment of this invention, an axial transporting structure with a plurality of spiral segments as the proceeding zones and a plurality of paddle segments as the blending zones is employed. Each of the spiral segments comprises one or more spiral structures, and each of the paddle segments comprises one or more paddle structures. Preferably, the spiral segments and the paddle segments are alternately arranged with each other in an appropriate ratio; i.e., the axial transporting structure comprises paddle segments and spiral segments arranged alternately with each other. Optionally, the ratio of the paddle segments to the spiral segments can be adjusted. For the application of pyrolyzing waste tires, if the blending segments are provided in a rather low percentage, it would be impossible to obtain the desired stirring and blending effect. On the other hand, if the blending segments are provided in a rather high percentage, the reaction chamber will be easily blocked by twisted steel wires in the waste tires. It has been found that for the pyrolysis of waste tires, it is desirable for the total length of the paddle segments to range from about 5% to about 35% of the length of the transporting structure. Preferably, the total length of the paddle segments ranges from about 10% to about 30% of the length of the transporting structure. Therefore, the pyrolysis furnace of the present invention can be used to provide the reaction chamber and the axial transporting structure necessary for the continuous pyrolysis apparatus, with the paddle segments functioning as the blending zones and the spiral segments functioning as the proceeding zones. The relevant structures and equivalent modifications thereof are just as described above and thus will not be described again herein.

[0029] The superheated steam generator communicates with the reaction chamber of the combustion chamber to supply superheated steam at a temperature higher than 100°C as the carrier gas of the gaseous pyro-products. The superheated steam generator itself may be provided with a steam boiler for generating steam. Steam thus generated is subsequently heated to form superheated steam at a high temperature. The steam can be heated in any appropriate manner, for example, by means of electric heating, fuel combustion, or a high-temperature gas. Alternatively, a superheated steam generator without a steam generating device may be used; in this case, in addition to communicating with the reaction chamber of the combustion chamber, the superheated steam generator further communicates with an external steam source to heat the steam transferred therefrom to form superheated steam.

[0030] To make an efficient use of the energy source, the superheated steam generator or portions of the superheated steam generator which transforms the steam into superheated steam can be optionally installed inside the combustion chamber along with the reactor to utilize heat from the heat generator more efficiently. In an embodiment of this invention, the superheated steam generator is designed into a tubular structure surrounding the outer wall of the combustion chamber. One end of the tubular structure is connected with the reaction chamber while the other end thereof is connected with a steam source. The heat supplied by the heat generator, while heating the reaction chamber, will also heat the superheated steam generator to supply superheated steam without any additional heating devices. Thus, the high-temperature gas from the heat generator heats the reaction chamber and the superheated steam generator of the combustion chamber at the same time to provide the desired temperature necessary for the pyrolysis reaction and supply superheated steam.

[0031] The aforesaid steam source may come from a steam generator, which may be a steam boiler of any appropriate type (e.g., an electric heating type, a combustion type, or a vacuum heating type), or may come from steam generated by other processes. Additionally, the steam generator may be provided with or without a combustor. For embodiments in which the steam generator does not have a combustor, the steam generator communicates with the combustion chamber, so that the waste heat from the reaction chamber (and the superheated steam generator) is introduced into the steam generator to heat water to form steam. Alternatively, heat supplied by the heat generator may be used directly to generate steam. Moreover, for embodiments in which a steam generator with a combustor is used, the necessary heat for steam generation may be supplied by the combustion of fuel oils and/or combustible gases recycled from the pyrolysis reaction.

[0032] Depending on the material to be pyrolyzed, various gaseous, liquid and/or solid products may be generated from the pyrolysis reaction. To effectively recycle these pyro-products, the continuous steam pyrolysis apparatus of the present invention may optionally further comprise one or more separating devices. For instance, when the apparatus is used to treat waste tires, the pyro-products may include gaseous oil-gas products such as pyro-oils, combustible gases and water as well as solid-material products such as steel wires and carbon black. Hence, the pyro-oil-gas processing system and/or a pyro-solid-material processing system can be further included at the downstream of the continuous steam pyrolysis apparatus of this invention.
The pyro-oil-gas processing system is generally adopted to treat gaseous products from the reaction chamber, and may comprise a purifying device for removing the solid impurities possibly entrained in the oil-gas, a condensing device for cooling down the oil-gas, an oil-water separating device for separating water from the condensed liquid, and/or a waste water processing device for further processing the separated water. Of course, the pyro-oil-gas processing system may optionally comprise other separating devices.

The purifying device, if used, usually communicates with the reaction chamber to remove dusts/particles (e.g., carbon black particles) possibly generated during the pyrolysis reaction. In an embodiment, a high-temperature filtering device with a pulse backwash capability is used as a purifying device. The high-temperature filtering device is usually provided with a filtering element (e.g., a metal mesh or a ceramic filtering cartridge) to remove the dusts/particles. The principles and technologies of “pulse backwash” are well-known to those with ordinary skill in the art and thus will not be further described herein. The filtering performance of filtering devices without the backwash capability, such as a powerful downdraft filtering device, usually degrades with continued operation of the devices. This is because the mesh is blocked by excessive particles or dusts filtered out from the gas. In contrast, the filtering device with the backwash capability may avoid the blocking phenomenon effectively to ensure a continuous reaction. When a filtering device with the pulse backwash capability is used, the superheated steam generator may be allowed to communicate with the high-temperature filtering device to intermittently supply the high-temperature filtering device with superheated steam. Alternatively, combustible gases obtained from a subsequent procedure of separating pyro-oil-gas may be fed back into the high-temperature filtering device to accomplish the pulse backwash action and to maintain a constant flow rate across the mesh.

The condensing device cools the gaseous components in the pyro-products by means of condensation to separate the pyro-products into pyro-oil, water, combustible gases and the like. Any appropriate condensing device may be optionally used. Generally, one or more condensers connected in series are used to separate the pyro-products into a plurality of components for subsequent use. In an embodiment, the condensing device consists of two condensers connected in series and is disposed at the downstream of the purifying device. This will ensure that the particle and dusts contained in the gaseous components are filtered out by the purifying device instead of entering the condensing device, which would otherwise cause the blocking of the apparatus or affect the economic value of the separated products.

Due to the higher condensing temperature of oils, the oils tend to be separated first from the separating device when processing the pyro-oil-gas. To prevent the condenser from being blocked due to the high viscosity of the condensed oils, a U-type pipeline is preferably used at the front end of the condensing device, so that the cooling water passes within the pipeline and the gaseous components to be condensed passes through the outer side of the U-type pipeline. In this way, the condensed oils will drip naturally at the bottom of the condenser and be transferred to the outside. Compared to the conventional condensing approach in which the material to be condensed flows within the pipeline while the cooling water passes outside the pipeline, this method can effectively prevent the possible blocking by oils and ensure the continuous operation of the apparatus.

The pyro-solid-material processing system may optionally comprise various appropriate physically/chemically separating devices. Generally, the pyro-solid-material processing system comprises a separating device (e.g., a sorting machine or a magnetic separator) and a crushing device (e.g., a grinding machine) for further processing the solid pyro-products. When treating waste tires, for example, the pyro-solid-material processing system comprises a sorting machine, a magnetic separator and a grinding machine. The sorting machine communicates with the reaction chamber to preliminarily remove steel wires in the waste tires from the solid pyro-products. The solid pyro-products that have been treated to preliminarily remove steel wires then are transported through the magnetic separator to further separate the residual steel wires and other metal substances. Finally, the final products are ground by the grinding machine into a desired particle size for recycling. Additionally, a sorting apparatus may be optionally provided at the downstream of the grinding machine to further sort the ground products.

The pyrolysis furnace and the continuous steam pyrolysis apparatus of the present invention may be used to pyrolyze various materials such as waste tires, waste plastics, waste wood, or agricultural biomass, and is preferably used to treat waste tires.

To explain this invention more clearly, an exemplary embodiment of the pyrolysis furnace and the continuous steam pyrolysis apparatus of the present invention, which may be used to treat waste tires, will be described hereinafter with reference to the attached drawings. In the attached drawings, the dimensions of individual elements are only provided for reference, but not for reflecting the actual dimensional scale.

As shown in FIG. 1, a schematic view of a pyrolysis furnace 1 is depicted therein. The pyrolysis furnace 1 comprises a reaction chamber 11, a driving device 13, a charge opening 151, a discharge opening 153, a pyro-oil-gas outlet 155, a secondary-refining inlet 157, and a communicating opening 17. The reaction chamber 11 comprises a first reaction region 113 and a second reaction region 115 installed one above the other and communicating with each other through the communicating opening 17. FIG. 2 illustrates a cross-sectional view of the pyrolysis furnace 1 shown in FIG. 1. Each of the first and the second reaction regions 113, 115 of the reaction chamber 11 has one axial transporting structure 21 therein, and each of the axial transporting structure 21 is connected to the corresponding driving device 13. Each of the transporting structure 21 has a central axis 211 and comprises a plurality of spiral segments 213 and a plurality of paddle segments 215. FIG. 3 depicts a partially enlarged view of the first and the second reaction regions 113, 115, where L2 represents the length of a single spiral segment and L3 represents the length of a single paddle segment. The total lengths of the spiral segments 213 and the paddle segments 215 are respectively calculated by summing the length of each segment occupied along the direction of the central axis 211. Generally, the sum of the lengths (L3) of the paddle segments of a single transporting structure 21 is controlled to range from about 5% to about 35% of the length of the transporting structure 21.

Waste tires are fed through the charge opening 151 into the reaction chamber 11 and pyrolyzed therein. The
pyro-oil-gas resulting from the pyrolysis reaction is fed out through the pyro-oil-gas outlet 155, while the pyro-solid-material products are fed out through the discharge opening 153. The waste tires are firstly fed into the first reaction region 113 of the reaction chamber 11 and moved forward gradually along the central axis of the transporting structure 21 during the pyrolysis reaction by the rotating transporting structure 21. In this course, the waste tires stay temporarily in the paddle segments 215 to be stirred and blended by the rotating paddles of the paddle segments. Because the first and the second reaction regions 113, 115 are installed one above the other, the waste tires under the pyrolysis reaction will drop into the second reaction region 115 when reaching the communicating opening 17 and then, with the rotation of the transporting structure 21 of the second reaction region 115, be moved forward to proceed with the pyrolysis reaction. The pyro-solid-material products are fed out through the discharge opening 153, while the pyro-oil-gas resulting from the pyrolysis reaction is fed out through the pyro-oil-gas outlet 155.

[0042] FIG. 4 is a schematic view illustrating the arrangement of an embodiment of a continuous steam pyrolysis apparatus of the present invention. The continuous steam pyrolysis apparatus primarily comprises a combustion chamber 31, a combustion furnace 33 and a steam boiler 39. As shown in FIG. 5, the pyrolysis furnace 1 as shown in FIG. 1 is disposed in the combustion chamber 31, while a tubular superheated steam generator 311 surrounds the reaction chamber 11 of the pyrolysis furnace 1.

[0043] Hereinafter, the pyro-oil-gas processing system used for processing the pyro-oil-gas generated in the combustion chamber 31 will be described. As shown in FIG. 4, the pyro-oil-gas processing system comprises a high-temperature filtering device 351, a condensing device consisted of a first and a second condenser 352a, 352b, an oil-water separating tank 357, a gas stabilizing tank 355 and a waste water processing device 359. The combustion chamber 31 has a pyro-oil-gas outlet 155 and a first hot air outlet P19, wherein the outlet 155 communicates with the pyro-oil-gas inlet P1 of the high-temperature filtering device 351 and the outlet P19 communicates with a second hot air outlet P20 of the steam boiler 39. In addition to the pyro-oil-gas inlet P1, the high-temperature filtering device 351 further comprises an oil-gas outlet P2 and a backwash air inlet P25, wherein the outlet P2 communicates with the first condensation inlet P3 of a first condenser 352a. The inlet P25 of this embodiment is adapted to guide the superheated steam generated by the superheated steam generator 311 into the high-temperature filtering device 351. In addition to the first condensation inlet P3, the first condenser 352a further comprises a first liquid inlet P4 and a first air outlet P5 communicating with the oil tank opening P9 of an oil tank 353 and a second condensation inlet P6 of a second condenser 352b respectively. In addition to the second condensation inlet P6, the second condenser 352b further comprises a second liquid outlet P7 and a second gas outlet P8 communicating with a second liquid inlet P10 of the oil-gas separating tank 357 and a second gas inlet P11 of a gas stabilizing tank 355 respectively. In addition to the second gas inlet P11, the gas stabilizing tank 355 further comprises a combustible gas outlet P15 communicating with a fuel inlet P16 of the combustor 33. Optionally, the outlet P15 may further communicate with the backwash gas inlet P25 (not shown).

[0044] In addition to the fuel inlet P16, the combustion furnace 33 further comprises an air outlet P17 communicating with the first hot air inlet P18 of the combustion chamber 31. In addition to the second liquid inlet P10, the oil-water separating tank 357 further comprises an oil outlet P12 and a water outlet P13 communicating with the oil tank opening P9 of the oil tank 353 and the waste water inlet P14 of the water processing device 359 respectively.

[0045] In the embodiment of the steam pyrolysis apparatus, the pyro-solid-material processing system is further included to treat solid products generated in the reaction chamber 11. As shown in FIG. 4, the pyro-solid-material processing system comprises a sorting machine 371, a magnetic separator 373, a first bag-type collector 377a and a second bag-type collector 377b. The sorting machine 371 comprises a primary processing inlet P27, a primary process gas outlet P28 and a primary solid product outlet P29. The inlet P27 communicates with the discharge opening 153 of the reaction chamber 11 to receive solid-material products generated in the reactor 11, and communicates with the hot air inlet P22 of the second bag-type collector 377b and a secondary processing inlet P30 of the magnetic separator 373 via the outlets P28 and P29 respectively. The magnetic separator 373 further comprises a secondary processing outlet P31 that communicates with a tertiary processing inlet P32 of the grinding machine 375. The grinding machine 375 further communicates with the filtering inlet P34 of the first bag-type collector 377a via a tertiary processing outlet P33.

[0046] In addition to the third hot air inlet P22, the second bag collector 377b further comprises a third hot air inlet P23 communicating with the waste gas inlet P26 of a waste gas processing device 379. Meanwhile, the steam boiler 39 communicates with the third hot air inlet P22 of the second bag-type collector 377b via a second hot air outlet P21 and communicates with the superheated steam generator 311 via a steam outlet P24.

[0047] Hereinafter, the process in which steam pyrolysis apparatus illustrated above treats waste tires will be explained. Optionally, prior to the pyrolysis process, a pre-processing device such as a crusher or a cutting machine is used to pre-process the waste tires into an appropriate size. Then, the waste tire granules with the appropriate size (usually cut into a particle size from about 5 cm to about 7 cm) are fed into the reaction chamber 11 of the pyrolysis furnace 1 via the charge opening 151 with a speed of about 1000 kg/hour. At this point, the temperature outside the pyrolysis furnace 1 is kept between about 700°C and about 1000°C to heat the superheated steam generator 311 and keep the temperature of the reaction chamber 11 between about 350°C and 550°C, and preferably between about 350°C and 480°C. Meanwhile, the superheated steam generated by the superheated steam generator 311 is introduced into the reaction chamber 11 to participate in the pyrolysis reaction.

[0048] The waste tire granules are transported by the transporting structure 21 and pass through the proceeding zones and the blending zones alternately (i.e., pass through the spiral segments 213 and the paddle segments 215 alternately) in the reaction chamber 11 to be pyrolyzed completely. FIG. 6 illustrates how a material 22 to be pyrolyzed (e.g., waste tire granules) passes through the first reaction region 113 of the reaction chamber 11. More specifically, the material 22 is moved forward in one spiral segment 213 and accumulates gradually, and is then stirred and blended upon reaching one paddle segment 215, after which the material 22 gradually
falls into a next spiral segment 213 and keeps moving forward. When the material is transported to the end of the first reaction region 113, a residual carbon black mixture and un- pyrolyzed waste tire granules fall into the second reaction region 115 via the communicating opening 17 to proceed with the pyrolysis. The material passes through the second reaction region 115 in substantially the same way as that in the first reaction region 113. During the pyrolysis, oil-gas resulting from the pyrolysis reaction is transported to the pyro-oil-gas processing system, and the non-gaseous pyro-products are either transported to the pyro-solid-material processing system or, optionally, fed into the second reaction region 115 via the secondary refining inlet 157 for secondary refining. In more detail, the pyro-oil-gas flows into the high-temperature filtering device 351 where carbon black particles therein are removed through, for example, a high-temperature steam pulse backwash process. Generally speaking, a high-temperature filtering device 351 equipped with a porous ceramic cartridge or a metal mesh may be employed, wherein the operation temperature is controlled to range from about 280°C to about 450°C and the filtering rate is controlled to range from 1 cm/second to 3 cm/second.

[0049] Subsequently, the pyro-oil-gas that the carbon black has been removed is subjected to a condensing process, which is usually a two-stage condensing process. In particular, as shown in FIG. 4, the pyro-oil-gas is introduced into the first condenser 352a, first to cool down the pyro-oil-gas to a temperature of about 110°C. The condensed oils thus obtained may be processed in a subsequent process for recycling, so that the residual pyro-oil-gas proceeds to the second condenser 352b, which is cooled down to a temperature of about 40°C. The condensed oils thus separated may also be processed in a subsequent process for recycling, and the condensed water is optionally subjected to a waste water treatment process for recycling or disposal. The condensed pyro-gases may also be optionally subjected to a gas stabilizing process, and then fed into the combustion furnace 33 to further supply the necessary heat for use in this invention.

[0050] In the case of pyrolysis waste tires, the material to be pyrolyzed usually comprises metal pieces such as steel wires, and therefore a sorting process may be carried out first on the pyro-products resulting from the reaction. For example, non-gaseous pyro-materials from the pyrolysis may be transported to the sorting machine 371 to preliminarily remove the steel wires and carbon black and cool down the pyro-solid material (generally cooled down to a temperature lower than 100°C). In this step, the residual gaseous components in the pyro-materials are fed into the second bag-type collector 377b to remove carbon black particles, and are subsequently processed by the waste gas processing device 379 for emission. The pyro-solid materials with the steel wires are removed preliminarily and are subsequently transported to the magnetic separator 373 to further remove the steel wires and carbon black. The carbon black collected is subsequently ground to the desired particle size. The carbon black is usually ground to a particle size capable of passing through a screen sized 200 mesh to be recycled.

[0051] In this embodiment, diesel oil or fuel oil is used as the fuel of the combustion furnace 33 at the early stage of the operation, and upon commencement of the pyrolysis reaction, combustible gases resulting from the pyrolysis reaction may be used as a fuel to reduce the cost. Here, the fuel has a flow rate of about 80 liters/hour. A high-temperature gas generated by the combustion furnace 33 is introduced into the combustion chamber 31 through, for example, fan drafting. The high-temperature gas maintains the temperature inside the combustion chamber 31 within a range of about 700°C to about 1000°C, and heats the pyrolysis furnace 1 and the superheated steam generator 311 to obtain a temperature necessary for the pyrolysis reaction (about 350°C to about 550°C) in the reaction chamber 11 of the pyrolysis furnace 1. The high-temperature gas within the combustion chamber 31 may then be transferred to the steam boiler 39 to heat water to form steam. In this respect, this invention does not preclude the use of a steam boiler 39 equipped with a combustor in itself. In other words, the steam boiler 39 may be heated by the high-temperature gas from the combustion chamber 31, the hot air generated in the combustion furnace 33, and/or the other combustor equipped in the steam boiler 39 itself to generate steam. Likewise, the combustor in the steam boiler 39 may also utilize combustible gases resulting from the pyrolysis reaction as a fuel to reduce the costs.

[0052] On the other hand, steam generated in the steam boiler 39 is used by the superheated steam generator 311 to generate superheated steam, and may also be used by the high-temperature filtering device 351 to execute a steam pulse backwash process to remove undesired particles. In more detail, a portion of the steam generated in the steam boiler 39 is transferred to the superheated steam generator 311 via the steam outlet P24, and then flows forward in the superheated steam generator 311 where it is heated by the high-temperature gas in the combustion chamber 31 to finally form superheated steam. A portion of the superheated steam is introduced into the reaction chamber 11 for use as a carrier gas in the pyrolysis reaction, while another portion of the superheated steam is introduced into the high-temperature filtering device 351 via the backwash gas inlet P25 for pulse backwashing on a regular or irregular basis, thereby effectively preventing the blocking of the device. Here, as previously described, stabilized combustible gases from the gas stabilizing tank 355 may also be fed into the high-temperature filtering device 351 via the backwash gas inlet P25 to conduct a pulse backwash process. Accordingly, the superheated steam and combustible gases may be used in combination depending on the arrangement and conditions of energy sources/materials in the whole apparatus. For example, the superheated steam from the superheated steam generator 311 and the combustible gases from the gas stabilizing tank 355 may be used alternately.

[0053] In summary, the pyrolysis furnace of the present invention is unique in that the transporting structure thereof has paddle segments serving as blending zones which ranges from about 5% to about 35% of the transporting structure in length. This percentage, a result obtained from numerous tests by the inventors, not only prevents the incomplete pyrolysis due to insufficient stirring when only spiral structures are used, but also prevents the blocking of the apparatus (e.g., twisting of steel wires in the waste tires) due to a high percentage of paddle structures.

[0054] Furthermore, in addition to the aforementioned pyrolysis furnace, the continuous steam pyrolysis apparatus of the present invention may further comprise a purifying device and/or a condenser designed with a U-type pipeline. The purifying device is adapted to remove particles (e.g., carbon black particles) from the pyro-gases, which helps to improve the quality of resultant oils, prevent the blocking of a condensing device at the downstream thereof, and reduce the cost of a subsequent oil refining process. Also, the particles (e.g.,
carbon black particles) thus collected deliver better economic outcomes. Moreover, in the condenser with a U-type pipeline design used in this invention, the cooling water flows within the pipeline, while the pyro-oil-gas flows along the outer side of the pipeline to prevent blocking.

Furthermore, the continuous steam pyrolysis apparatus of this invention utilizes superheated steam as the carrier gas. The use of the steam can prevent an explosion that would likely occur in conventional dry-type pyrolysis processes. On the other hand, the steam can decrease the sulfur content in the pyro-products and ensure a better economic value thereof.

Due to these advantages, the apparatus of the present invention is capable of efficiently pyrolyzing materials, especially waste tires, on a continuous basis, and the products thus obtained have better economic values.

The above disclosure is related to the detailed technical contents and inventive features thereof. People with ordinary skill in the field may proceed with a variety of modifications and replacements based on the disclosures and suggestions of the invention as described without departing from the characteristics thereof. Nevertheless, although such modifications and replacements are not fully disclosed in the above descriptions, they have substantially been covered in the following claims as appended.

What is claimed is:

1. A pyrolysis furnace for a continuous steam pyrolysis apparatus, comprising a reaction chamber with a charge opening and a discharge opening, and one or more axial transporting structures installed in the reaction chamber, wherein each of the transporting structures has a central axis and comprises one or more spiral segments and one or more paddle segments, and the total length of the paddle segments along the central axis direction ranges from about 5% to about 35% of the length of the transporting structure.

2. The pyrolysis furnace as claimed in claim 1, wherein the total length of the paddle segments ranges from about 10% to about 30% of the length of the transporting structure.

3. The pyrolysis furnace as claimed in claim 1, wherein the transporting structure has a plurality of spiral segments and a plurality of paddle segments that are alternately arranged with each other, and each of the spiral segments is substantially identical in length and each of the paddle segments is substantially identical in length.

4. The pyrolysis furnace as claimed in claim 1, wherein the reaction chamber comprises a plurality of reaction regions communicating with one another, and each of the reaction regions comprises one said transporting structure.

5. The pyrolysis furnace as claimed in claim 4, wherein the reaction chamber comprises two reaction regions.

6. The pyrolysis furnace as claimed in claim 1, which is used for the treatment of waste tires.

7. A continuous steam pyrolysis apparatus, comprising: a heat generator; a combustion chamber communicating with the heat generator, comprising: a reaction chamber with a charge opening and a discharge opening; and one or more axial transporting structures installed in the reaction chamber, wherein each of the transporting structures has a central axis and comprises one or more proceeding zones and one or more blending zones, and the total length of the blending zones along the central axis direction ranges from about 5% to about 35% of the length of the transporting structure; and a superheated steam generator communicating with the reaction chamber.

8. The apparatus as claimed in claim 7, which further comprises a steam generator communicating with the superheated steam generator.

9. The apparatus as claimed in claim 7, wherein the total length of the blending zones ranges from about 10% to about 30% of the length of the transporting structure.

10. The apparatus as claimed in claim 7, wherein the transporting structure has a plurality of proceeding zones and a plurality of blending zones that are alternately arranged with each other, and each of the proceeding zones is substantially identical in length and each of the blending zones is substantially identical in length.

11. The apparatus as claimed in claim 7, wherein the proceeding zones are spiral segments and the blending zone are paddle segments.

12. The apparatus claimed in claim 7, wherein the superheated steam generator is tube-shaped and surrounds the outside of the reaction chamber.

13. The apparatus as claimed in claim 7, wherein the reaction chamber comprises a plurality of reaction regions communicating with one another, and each of the reaction regions comprises one said transporting structure.

14. The apparatus as claimed in claim 13, wherein the reaction chamber comprises two reaction regions.

15. The apparatus as claimed in claim 7, which further comprises a pyro-oil-gas processing system at the downstream of the reaction chamber, wherein the pyro-oil-gas processing system comprises a purifying device, a condensing device, and optional, an oil-water separating device and/or a waste water processing device, and the purifying device is a high-temperature filtering device and communicates with the superheated steam generator.

16. The apparatus as claimed in claim 15, wherein the condensing device comprises two or more condensers in series, wherein the condenser at one end communicates with the heat generator, and the condenser at the other end communicates with the purifying device and is provided with an U-type pipe for passing cooling water.

17. The apparatus as claimed in claim 7, which further comprises a pyro-solid-material processing system at the downstream of the reaction chamber, comprising: a sorting machine; a magnetic separator; and a grinding machine.

18. The apparatus as claimed in claim 7, which is used for the treatment of waste tires.

19. The apparatus as claimed in claim 7, which further comprises a pre-processing device at the upstream of the reaction chamber, communicating with the reaction chamber through the charge opening, wherein the pre-processing device is a cutting machine.

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