

(19)



(11)

EP 4 249 572 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

27.09.2023 Bulletin 2023/39

(21) Application number: **22176380.8**

(22) Date of filing: **31.05.2022**

(51) International Patent Classification (IPC):

C10G 1/10 (2006.01)

C10B 47/44 (2006.01)

C10B 53/07 (2006.01)

B01F 27/1145 (2022.01)

B01F 27/721 (2022.01)

B01F 35/95 (2022.01)

(52) Cooperative Patent Classification (CPC):

C10G 1/10; B01F 27/1145; B01F 27/721;

B01F 35/95; C10B 47/44; C10B 53/07

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA ME

Designated Validation States:

KH MA MD TN

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(30) Priority: **25.03.2022 EP 22164452**

(54) PLASTIC WASTE THERMOLYSIS REACTOR

(57) The disclosure provides a reactor for thermolysis of plastic waste in which reaction residue and carbonization products are continuously removed. The reactor chamber (110) comprises an agitating device (130) that is housed within the reactor chamber (110) for processing

plastic waste material, wherein the agitating device (130) comprises a rotating helix assembly with a first helix (131) and a second helix (132), coaxially positioned in respect to the first,

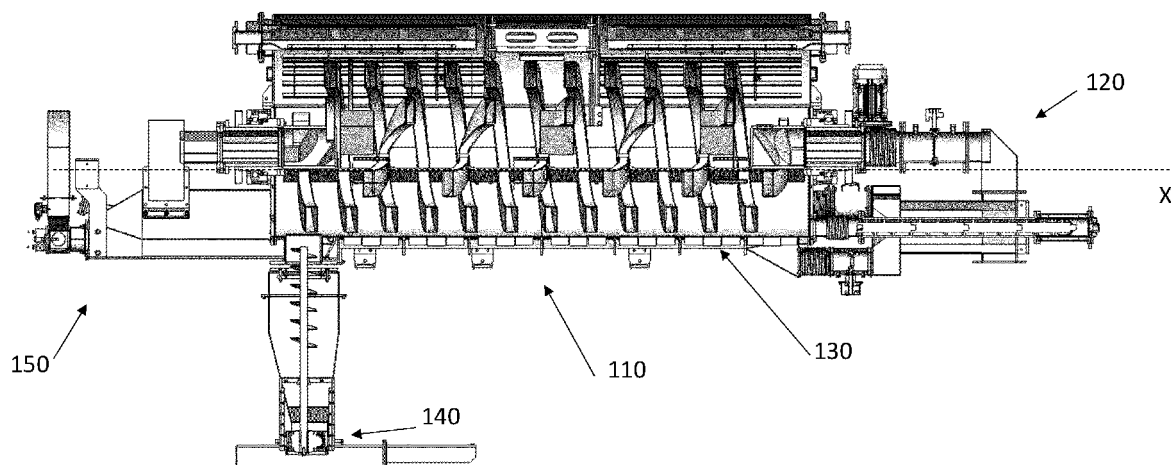


Figure 5

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Description**FIELD**

- 5 **[0001]** The present disclosure provides a reactor for conducting plastic waste thermolysis with continuous feeding of plastic raw material and automatic removal of carbonization products and any other reaction residues.

BACKGROUND

- 10 **[0002]** The process of thermolysis (or pyrolysis) is a well-known method of chemical reaction in which a relatively large compound is broken down into molecules due to high temperatures. Such process for converting plastic waste into liquid fuels is generally acknowledged as a convenient way to handle plastic waste, since the cost is manageable, and the final product (liquid fuel) may have properties that are more or less like the common petroleum fuels. In addition, the products that are deriving from the thermolysis of plastic provide the advantage of not containing any sulfur, as the petroleum products do, thereby being more environmentally friendly, since sulfur is a known pollutant that also affects the health of the public. Conventional reactors however, that convert plastic waste to usable fuel do show some drawbacks, mainly related to the thermal efficiency of the overall process. Further, in conventional reactors, the process is not continuous, meaning that when a batch of raw material is process through a thermolysis reactor chamber, then the entire operation should stop to cool down the reactor and remove any carbon residues.
- 20 **[0003]** It is thus an object of the present disclosure to overcome the aforementioned drawbacks. The described thermolysis reactor for conducting plastic waste thermolysis is designed and based to continuous closed operation cycle in a way that is achieved maximum energy efficiency. In addition, due to the arrangement and the configuration of the helix assembly of the agitating device and, a relatively compact/controllable size of the equipment is succeeded, thereby allowing the installation of such equipment in a quite fast and precise manner in any workplace. Such arrangement
- 25 further allows for a continuous thermolysis reaction and a continuous extraction of syngas from the reactor, thus enhancing the efficiency of the overall process.

SUMMARY

- 30 **[0004]** According to aspects of the present disclosure there is provided a thermolysis reactor for conducting plastic waste thermolysis comprising a reactor chamber comprising an input end for receiving plastic waste and an output end for discharging synthesis gas, at least one gas burner, an agitating device that is housed within the reactor chamber for processing plastic waste material, a carbon rejection device and an exhaust gases collector, wherein the agitating device comprises a rotating helix assembly with a first helix and a second helix wherein each of the first and second helices is
- 35 hollow, thereby forming helical ducts for circulating exhaust gases to heat the plastic waste. The agitating device effectively uses the exhaust gases to heat the molten plastic waste within the reactor.
- [0005]** According to aspects of the disclosure, the first helix is positioned coaxially relative to the second helix such that plastic waste material is moved by the first helix towards the output end of the reactor chamber.
- [0006]** According to aspects of the disclosure, the direction of the second helix is opposite to the direction-of the first
- 40 helix.
- [0007]** According to aspects of the present disclosure, the first helix encloses the second helix.
- [0008]** According to aspects of the present disclosure, the second helix comprises an inner diameter and an outer diameter and wherein the inner diameter of the first helix is bigger than the outer diameter of the second helix.
- [0009]** According to aspects of the present disclosure, the inner diameter of the first helix is of about 600 to 700 mm, the outer diameter of the first helix is of about 900 to 1000 mm the outer diameter of the second helix is of about 500
- 45 mm and 600 mm and the inner diameter of the second helix is of about 200 mm and 300 mm.
- [0010]** According to aspects of the disclosure, the number of the turns of the first helix is greater than the number of turns of the second helix.
- [0011]** According to aspects of the present disclosure, the agitating device comprises an exhaust gas inlet and an exhaust gas outlet, wherein the exhaust outlet comprises a valve for regulating the flow of the exhaust gases.
- 50 **[0012]** According to aspects of the present disclosure, the reactor chamber is of semi-circular shape and wherein an outer surface of the reactor chamber comprises a plurality of heating jackets, configured to drive the exhaust gases towards the exhaust gas collector.
- [0013]** According to aspects of the present disclosure, each heating jacket comprises a control valve for controlling the flow of exhaust gases from each heating jacket.
- 55 **[0014]** According to aspects of the present disclosure, the reactor comprises at least one gear box that, when activated, is configured to initiate the rotation of the agitating device.
- [0015]** According to aspects of the disclosure, the reactor comprises one or more load cells, wherein said load cells

are removably attached on a bottom surface of the reactor and they are configured to monitor the supply of plastic waste material within the reactor.

[0016] According to aspects of the present disclosure, the carbon rejection device comprises a first valve for opening or closing a first port to the carbon rejection device, a residue chamber-for the storage of carbon residues, a helix that is mounted within the residue chamber and a second valve for opening or closing a second port of the residue chamber.

[0017] According to other aspects, the at least one of the first and second helices is surrounded by scraped segments that are designed such that they detach and transfer any residues to the carbon rejection device.

[0018] According to aspects of the disclosure, the reactor chamber comprises electrical resistors, wherein said electrical resistors are removably connected to an upper surface of the reaction chamber.

[0019] According to aspects of the disclosure, the agitating device defines a longitudinal axis X which is substantially parallel to a horizontal plane, wherein the pitch of the first helix is of about 200-250 mm and the pitch of the second helix is of about 400-500 mm.

[0020] In other aspects of the disclosure a method for plastic waste thermolysis is provided, comprising the steps of:

- continuously providing molten plastic waste to a thermolysis reactor at a temperature between 180 - 240 °C
- producing exhaust gases via at least one gas burner
- guiding the exhaust gases on an outer surface of the thermolysis reactor via at least one heating jacket
- guiding the exhaust gases in the helical ducts of at least one of the first and second helices of the agitating device
- continuously rotating the agitating device
- heating the plastic waste to a temperature between 370 - 430 °C, thereby converting the plastic waste to gaseous form.

[0021] According to aspects of the disclosure, the method comprises automatically rejecting the carbon residues that are produced during thermolysis via a carbon rejection device.

[0022] According to aspects of the disclosure, the method comprises the step of controlling the flow of the exhaust gases that are guided to the at least one heating jacket and to the agitating device.

[0023] Dependent embodiments of the aforementioned aspects of the disclosure are given in the dependent claims and explained in the following description, to which the reader should now refer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Aspects of an embodiment will be described in reference to the drawings, where like numerals reflect like elements:

- Figure 1 shows the main components of the thermolysis reactor
- Figure 2 shows an overview of the assembled thermolysis reactor
- Figure 3 shows an overview of the agitating device
- Figure 4 shows an overview of the carbon rejection device
- Figure 5 shows a cross-section of the thermolysis reactor
- Figure 6 shows a side view of agitating device
- Figure 7 shows a front view of agitating device

DETAILED DESCRIPTION

[0025] An embodiment of the thermolysis reactor according to aspects of the disclosure will now be described with reference to Figures 1-7. Although the reactor is described with reference to specific examples, it should be understood that modifications and changes may be made to these examples without going beyond the general scope as defined by the claims. In particular, individual characteristics of the various embodiments shown and/or mentioned herein may be combined in additional embodiments. Consequently, the description and the drawings should be considered in a sense that is illustrative rather than restrictive. The Figures, which are not necessarily to scale, depict illustrative aspects and are not intended to limit the scope of the disclosure. The illustrative aspects depicted are intended only as exemplary.

[0026] The term "exemplary" is used in the sense of "example," rather than "ideal." While aspects of the disclosure are amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit aspects of the disclosure to the particular embodiment(s) described. On the contrary, the intention of this disclosure is to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure.

[0027] As used in this disclosure and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the content clearly dictates otherwise. As used in this disclosure and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

[0028] Throughout the description, including the claims, the terms "comprising a," "including a," and "having a" should be understood as being synonymous with "comprising one or more," "including one or more," and "having one or more" unless otherwise stated. In addition, any range set forth in the description, including the claims should be understood as including its end value(s) unless otherwise stated. Specific values for described elements should be understood to be within accepted manufacturing or industry tolerances known to one of skill in the art, and any use of the terms

"substantially," "approximately," and "generally" should be understood to mean falling within such accepted tolerances. **[0029]** When an element or feature is referred to herein as being "on," "engaged to," "connected to," or "coupled to" another element or feature, it may be directly on, engaged, connected, or coupled to the other element or feature, or intervening elements or features may be present. In contrast, when an element or feature is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or feature, there may be no intervening elements or features present. Other words used to describe the relationship between elements or features should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.).

[0030] Spatially relative terms, such as "top," "bottom," "middle," "inner," "outer," "beneath," "below," "lower," "above," "upper," and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the drawings. Spatially relative terms may be intended to encompass different orientations of a device in use or operation in addition to the orientation depicted in the drawings. For example, if the device in the drawings is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0031] Although the terms "first," "second," etc. may be used herein to describe various elements, components, regions, layers, sections, and/or parameters, these elements, components, regions, layers, sections, and/or parameters should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer, or section from another region, layer, or section. Thus, a first element, component, region, layer, or section discussed herein could be termed a second element, component, region, layer, or section without departing from the teachings of the present disclosure.

[0032] Figure 1 illustrates the various components that, when assembled, form a thermolysis reactor (100) for conducting plastic waste pyrolysis. In detail, the reactor (100) comprises a reactor chamber (110) where the thermolysis reaction takes place, the reactor chamber comprising an input end for receiving plastic waste and an output end for discharging synthesis gas, at least one gas burner (150) for creating the necessary temperature for the heating distributors, an agitating device (130) that is housed within the reactor chamber (110) for processing plastic waste material with the usage of exhaust gases, thereby heating the plastic waste within the reactor, a carbon rejection device (140), and an exhaust gas collector (120). In addition, the agitating device (130) comprises a rotating helix assembly comprising a first helix (131) and a second helix (132) wherein each of the first and second helix is hollow, thereby forming helical ducts for circulating exhaust gases to heat the plastic waste. Further, such configuration of the rotating helix assembly results in the formation of a single screw system that comprises the first and the second helix (131, 132) where the first and second helix are rotating simultaneously.

[0033] In embodiments, the reactor chamber (110) and the helix assembly may be made by stainless steel which is known for its long-term value and the corrosion resistance that it provides. In addition, the reactor chamber (110) may have a semicircular shape and may be arranged horizontally relative to a horizontal plane. The reactor chamber (110) may be divided in two compartments which may be called in the herein disclosure as lower and upper part of the reaction chamber. The lower and the upper part may be separate components, so as to facilitate the installation of other components within the reactor and may be assembled together through suitable attaching means such as screws. In an example, the outer surface of the lower part of the reactor chamber (110) comprises a plurality of heating jackets (111), which in the described embodiment are limited to three, configured to drive the exhaust gases towards the exhaust gas collector (120). The exhaust gas collector (120) may comprise a chamber with nozzles that are connected with the helix assembly of the agitating device (130) of the reactor. In an example, the nozzles may be connected with flow regulating valves, and in particular proportional exhaust flow regulating valves, for controlling the exhaust gas flow. The exhaust gas collector (120) may further comprise a compartment where a screw (not shown) allows the insertion of the plastic waste into the reactor, in liquid state.

[0034] In an example, an internal surface of the upper part of the reactor chamber (110) may comprise electrical resistors that are removably connected to that upper surface of the reaction chamber. The usage of electrical resistors ensures that when the the syngas that is resulting from the thermolysis reaction passes from these sections that contain the resistors, the temperature at these points is at the desired level to achieve gasification and any small particles that have resulted from the thermolysis reaction but have not yet been gasified.

[0035] At least one gas burner (150) is provided for the diffusion of the exhaust gases. In the described example, two gas burners (150) are used to create the required temperature for the heating distributors, to achieve the optimal diffusion

of the exhaust gases. The gas burners (150) may be mounted on one side of the reactor chamber (110) and direct the exhaust gases through specific paths within the reactor (100) where the thermolysis reaction of the plastic takes place. The power of the gas burners is proportional to a wide range and a closed loop air / fuel ratio control is performed, to achieve maximum efficiency and low NOx levels. An important aspect of these gas burners is their multifunction . In detail and depending on availability, natural gas or liquefied petroleum gas (LPG) or any other gas or liquid or any other kind of energy can be used as the main fuel and non-condensable gases as supplementary fuel, where depending on the stock, the filling rate of the fuel mixture is automatically calculated.

[0036] In an embodiment, the agitating device (130) comprises an exhaust gas inlet and an exhaust gas outlet, wherein the exhaust gas outlet comprises a valve (123), in examples a proportional valve, for regulating the flow of the exhaust gases. By controlling the exhaust gas flow and as the exhaust gas passes through the helix assembly, the maximum heat energy efficiency to the material in the reactor core is achieved, increasing the heat transfer rate and therefore the overall reactor efficiency. The exhaust gases, after entering the agitating device through the exhaust inlet, they are split and they are flowing onto the first helix (131) and the second helix (132). On the other end of the agitating device, they are again mixed and they flow towards a common exhaust gas outlet where the valve (123) is located and connected to the exhaust gas collector (120).

[0037] The plastic waste enters the thermolysis reactor (100) at a temperature of 220°C, in molten state. Its temperature begins to rise, using the heat of the exhaust gases which are led to the thermolysis reactor (100). In an example, the exhaust gases are led to the external surface of the reactor (100), and more specifically to the exhaust gas collector (120), through specially designed ducts that form a plurality of heating jackets (111), which in the described example are three. In each heating jacket, there is a proportional flow control valve (124) at the exhaust outlet, for regulating the flow of the exhaust gases. By controlling the flow of exhaust gases through each heating jacket, a uniform distribution of temperature is achieved on the walls of the outer surface of the reactor (100), thereby achieving maximum temperature absorption by the plastic material that comes in contact with them. Taking into account the main parameters that affect the absorption of thermal energy, the following simplified form results:

$$\text{Energy recovery} = \text{Flow} * \text{Temperature difference}$$

$$\text{Energy recovery} = \text{Temperature difference} * \text{Surface}$$

$$E_r = Q_{\text{raw material}} * \Delta t_{\text{raw material}}$$

$$\Delta t = t_{in} - t_{out}$$

where, E_r = Energy recovery

Q = Material flow / h

Δt = Temperature difference

t_{in} = Inlet temperature

t_{out} = Output temperature

Summarizing the above, with the control of the exhaust temperature of the three (3) heating jackets and keeping it constant, ensures maximum absorption of temperature by the material from the total surface of the reactor (100).

[0038] In an embodiment, the first helix (131) is positioned coaxially relative to the second helix such that plastic waste material is moved by the first helix (131) towards the output end of the reactor chamber (110). The exhaust gases are led inside the thermolysis reactor (100) through the helical paths. In an example, each of the first helix (131) and the second helix (132) comprises an inner diameter and an outer diameter wherein the inner diameter of the first helix (131) is bigger than the outer diameter of the second helix (132) thereby creating an arrangement where the first helix encloses the second helix, or to further simplify, the second helix (132) is inside the first helix (131). In an example, the inner diameter (d_1) of the first helix (131) is of about 600-700mm, the outer diameter (d_2) of the first helix is of about 900 to 1000 mm, the outer diameter (d_3) of the second helix (132) is of about 500 mm and 600 mm and the inner diameter (d_4) of the second helix is of about 200mm and 300mm. Further, the thickness of the helices (131, 132) may be between 3-10mm and in particular 5mm. Preferably, the two helices are connected through connecting means, in such a way that they rotate synchronously through the same rotating means. In one embodiment both helices (131, 132) rotate clockwise. In an example, the direction of the second helix (132) is opposite to the direction of the first helix (131). More specifically, the helix direction of the first helix can be clockwise, or right-handed and the direction of the second helix

counterclockwise or left-handed. The opposite combination is also possible, without departing from the teaching of the present disclosure. By rotating the helix assembly, the first helix (131) that has the bigger diameter pushes the material to always move in the opposite direction from the inner second helix (132). In this way two flow streams of the material are formed, where with the repeated circulation of the flow, the heat is transferred directly and evenly throughout the material, making it completely homogenized. In an example, the number of the turns of the first helix (131) is greater than the number of the turns of the second helix. In an example the turns of the first helix (131) may be between nine to twelve (9-12) and in particular eleven (11) and the turns of the second helix (132) may be between five to eight (5-8) and in particular six (6). In an example, the agitating device (130) defines a longitudinal axis X which is substantially parallel to a horizontal plane, wherein the pitch (h1) of the first helix (131) is of about 200-250mm and in particular 225 mm and the pitch (h2) of the second helix is of about 400-500mm and in particular 450 mm. The skilled person may interpret the pitch of a helix as the height of one complete helix turn, measured parallel to the axis of the helix, as it can be seen in figure 7. Such arrangement is beneficiary since the size of the overall equipment is relatively small, thereby facilitating its installation to any suitable location. In addition, such configuration provides the advantage of having agitation and homogenization of the plastic material with continuous flow while heating with direct and uniform transfer of heat to the material from the reactor core, where the residence time of the raw material in the reactor is reduced to the minimum.

[0039] The temperature inside the reactor (100) may reach 370°C to 425°C. At this temperature, the plastic becomes gaseous. The reaction of the plastic at this temperature causes the plastic carbon chain lengths to randomly break into various lengths. The pressure inside the reactor (100) may rise to 3 bar. The syngas resulting from the thermolysis reaction pass through the upper surface of the reactor chamber (110) that comprises the electrical resistors. As previously described, in this way the temperature at these points is at the desired level to achieve gasification and any small particles that have resulted from the thermolysis reaction but have not yet been gasified.

[0040] A significant advantage of the reactor (100) according to the present disclosure is that the operation of the reactor (100) is continuous. In an example, the reactor (100) comprises at least one gear box (170) that, when activated, is configured to initiate the rotation of the agitating device (130). The electric gearbox (170) enables the helix assembly to rotate, meaning that the rotation of each of the first and second helices (131, 132) may be activated by a single electric gear box. In an example, a pair of electric gearboxes is provided, as shown in figure 3, as a precaution to avoid any distortions across the length of the rotating helix assembly. In other examples, a pair of electric gearboxes (170) may also be provided for activating the rotation of the first and second helices (131, 132). In that specific example, the rotation of the first and second helix will be independent from each other since each helix will have assigned its own electric gear box for initiating the relevant helix rotation.

[0041] In an example, the reactor (100) comprises one or more load cells, wherein said load cells are removably attached on a bottom surface of the reactor (100) and they are configured to monitor the supply of plastic waste material within the reactor (100). In that way, the reactor (100) is automatically checked for its continuous feeding with plastic material, while the completeness of the plastic waste within the reactor is successfully maintained.

[0042] In embodiments, the carbon rejection device (140) comprises a first valve (141) for opening or closing a first port to the carbon rejection device (140), a residue chamber (142) for the storage of carbon residues, a helix that is mounted within the residue chamber (142) and a second valve (143) for opening or closing a second port to the residue chamber (142). Any suitable valve should be foreseen for carrying out the described operation. The first and second valves may be, but not limited to, proportional. With the usage of specific software, the degree of performance of the reactor (100) is calculated and when it drops below a certain threshold, the regeneration process begins. When the carbon residues reach a certain level, then automatically all parts of the reactor (100) are put into proper operation so that the reactor (100) enters regenerative mode. At this stage the carbon rejection device (140) is activated, for example, through specially designed software means, and the residues generated by the thermolysis process are discarded from the reactor (100). When the reactor (100) enters in regenerative mode, the first valve (141) is activated, and the first port of the carbon rejection device (140) opens. Meanwhile, the port at the bottom of the residue chamber (142) is closed. The helix (144) of the carbon rejection device (140) starts moving to enter the reactor (100). Through the helix, the carbon residues that have accumulated for example above the port of the first valve (141) are discarded in the residue chamber (142) and the helix (144) is moved to its initial position.

[0043] In an example, at least one of the first and second helices (131, 132) is surrounded by scraped segments that are designed such that they detach and transfer any residues to the carbon rejection device (140). In the described embodiment, only the first helix (131) is surrounded by such scraped segments. In detail, the first valve (141) is closed and the agitating device (130) rotates to bring carbon residue above the port of the first valve (141) and subsequently the agitating device stops its rotation. Next, the first valve (141) opens, and the helix (144) of the carbon rejection device (140) is activated and at the same time it moves to enter the reactor (100). Through the helix (144), the carbon residues that have accumulated above the port of the first valve (141) are discarded in the residue chamber (142). In a next step of the operation, the helix (144) is moved to its initial position and the first valve (141) closes. At that point, the agitating device (130) rotates again with a specific step to bring carbon residue above the port of the first valve (141). At that

point, the agitating device (130) stops rotating and the first valve (141) opens. The helix (144) of the carbon rejection device (140) is activated and at the same time it moves to enter the reactor (100) to discard the accumulated residues in the residue chamber (142).

[0044] The above-described steps are repeated until the residue chamber (142) is filled. When the residue chamber (142) is full, a valve (143), in examples a proportional valve (143) is actuated and the port that is located at a bottom surface of the residue chamber (142) opens, thereby disposing the residues, for example in an external container for further processing or final disposal. The above procedure is repeated and lasts until all the amount of carbon residue present in the reactor (100) is discarded. At the end of this reactor regeneration phase, all parts of the unit are automatically put into production process mode. The regeneration process does not require the reduction of the reactor temperature, so the accumulated energy in the reactor mass remains and thus the recovery of its energy is not required to continue the production process. In this way the regeneration time of the reactor is limited only to the disposal of carbon residues without the loss of its thermal energy.

[0045] The plastic materials that are suitable for the conversion according to the present disclosure may be, but not limited to, PE (polyethylene), PET (polyethylene terephthalate), HDPE (high density polyethylene), LDPE (low density polyethylene), PP (polypropylene), PS (polystyrene), ABS (acrylonitrile-butadiene-styrene copolymer). The plastic material may preferably be in cylindrical shaped particles ('spheres') with a maximum diameter of 10mm. In an example, the most preferred feedstock from the above list of materials for the production of liquid hydrocarbons are the PE, PP and PS thermoplastics. The addition of thermosetting plastics, wood, and paper to the feedstock results to the formation of carbonous substances and lowers the rate and yield of liquid products. This happens because the thermolysis products are directly related to the chemical composition and chemical structure of the plastics, since the chemical composition of the feedstock affects the thermolysis process. It has to be noted, that is of significant importance if the plastic feedstock contains PVC, since the PVC thermolysis the resulting products may contain HCl that is found to be hazardous for the fuels. In that case wherein the feedstock comprises PVC the plant should also comprise a re-treatment system to remove HCl from the resulting pyrolysis products. The thermolysis products may be grouped as petroleum gases, petrol, kerosene, diesel and WAX (>C₅₀). The above-mentioned fuels may contain hydrocarbon group with different carbon chain lengths as given in below Table 1. However, it has to be contemplated that there are also other ways to describe the hydrocarbons such as boiling range, phase of products at room temperature etc.

Table 1. Hydrocarbon range in commercial fuels

Fuels	LPG	Petrol	Kerosene	Diesel	Heavy Fuel oil
Hydrocarbons	C ₁ to C ₄	C ₅ to C ₁₀	C ₁₀ to C ₁₆	C ₁₄ to C ₂₀	C ₂₀ to C ₇₀

[0046] In an embodiment, a method for plastic waste thermolysis is provided. Such method comprises the steps of continuously providing plastic waste to a thermolysis reactor (100) at a temperature between 180 - 240 °C, producing exhaust gases via at least one gas burner (150), guiding the exhaust gases on an outer surface of the thermolysis reactor (100) via at least one heating jacket (111), guiding the exhaust gases in the helical ducts of at least one of the first and second helices of the agitating device (130), rotating the agitating device (130), heating the plastic waste to a temperature between 370 - 430 °C, thereby converting the waste plastic to gaseous form. In an example, the method may further comprise the step of automatically rejecting the carbon residues that are produced during thermolysis via a carbon rejection device (140). In addition, the method may further comprise the control of the flow of the exhaust gases that are guided to the at least one heating jacket (111) and to the agitating device (130). Such method enhances the overall thermal efficiency, since the temperature difference between the liquid plastic material that enters the reactor (~220°C) and the temperature at which the heat treatment reaction takes place (370°C - 425°C) is relatively low, while it ensures an uninterrupted continuous thermolysis reaction with continuous extraction of syngas from the reactor and rejection of any carbon residues.

[0047] It should be noted that the above embodiments are only for illustrating and not limiting the technical solutions of the present disclosure. Although the present disclosure has been described in detail with reference to the above embodiments, those skilled in the art should understand that any modifications or equivalent substitutions of the present disclosure are intended to be included within the scope of the appended claims.

[0048] Although the present disclosure herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present disclosure.

[0049] It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the appended claims.

Claims

1. A thermolysis reactor (100) for conducting thermolysis of plastic waste comprising:

- a reactor chamber (110) comprising an input end for receiving plastic waste and an output end for discharging synthesis gas,
- at least one gas burner (150),
- an agitating device (130) that is housed within the reactor chamber (110) for processing plastic waste material,
- a carbon rejection device (140),
- an exhaust gases collector (120).

wherein the agitating device (130) comprises a rotating helix assembly with a first helix (131) and a second helix (132), wherein each of the first and second helices is hollow, thereby forming helical ducts for circulating exhaust gases to heat the plastic waste.

2. The reactor (100) of claim 1 wherein the first helix (131) is positioned coaxially relative to the second helix (132) such that plastic waste material is moved by the first helix (131) towards the output end of the reactor chamber (110).

3. The reactor (100) of claims 1-2 wherein the two helices are connected and the direction of the second helix (132) is opposite to the direction of the first helix (131).

4. The reactor (100) of claims 1 -3 wherein the first helix (131) encloses the second helix (132).

5. The reactor (100) of claims 1 to 4 wherein each of the first helix (131) and the second helix (132) comprises an inner diameter and an outer diameter and wherein the inner diameter of the first helix (131) is bigger than the outer diameter of the second helix (132).

6. The reactor (100) of claims 5 wherein the inner diameter (d1) of the first helix (131) is of about 600 to 700 mm, the outer diameter (d2) of the first helix is of about 900 to 1000 mm, the outer diameter (d3) of the second helix (132) is of about 500 mm and 600 mm and the inner diameter (d4) of the second helix is of about 200 mm and 300 mm.

7. The reactor (100) of any of the preceding claims wherein the number of the turns of the first helix (131) is greater than the number of turns of the second helix (132).

8. The reactor (100) of any of the preceding claims wherein the agitating device (130) comprises an exhaust gas inlet and an exhaust gas outlet, wherein the exhaust gas outlet comprises a valve (123) for regulating the flow of the exhaust gases.

9. The reactor (100) according to any of the preceding claims wherein the reactor chamber (110) is of semi-circular shape and wherein an outer surface of the reactor chamber (110) comprises a plurality of heating jackets 111, configured to drive the exhaust gases towards the exhaust gas collector (120).

10. The reactor (100) according to claim 9 wherein each heating jacket (111) comprises a control valve (124) for controlling the flow of exhaust gases from each heating jacket (111).

11. The reactor (100) of any of the preceding claims comprising at least one gear box (170) that, when activated, is configured to initiate the rotation of the agitating device (130).

12. The reactor (100) according to any of the preceding claims comprising one or more load cells, wherein said load cells are removably attached on a bottom surface of the reactor (100) and they are configured to monitor the supply of plastic waste material within the reactor (100).

13. The reactor (100) according to any of the preceding claims wherein the carbon rejection device (140) comprises a first valve (141) for opening or closing a first port of the carbon rejection device (140) a residue chamber (142) for the storage of carbon residues, a helix (144) that is mounted within the residue chamber (142) and a second valve (143) for opening or closing a second port of the residue chamber (142).

14. The reactor (100) according to any of the preceding claims wherein at least one of the first and second helices (131,

132) is surrounded by scraped segments that are designed such that they detach and transfer any residues to the carbon rejection device (140).

5 15. The reactor (100) according to any of the preceding claims wherein the reactor chamber (110) comprises electrical resistors, wherein said electrical resistors are removably connected to an upper surface of the reaction chamber (110).

10 16. The reactor (100) according to any of the preceding claims wherein the agitating device (130) defines a longitudinal axis X which is substantially parallel to a horizontal plane, wherein the pitch (h1) of the first helix (131) is of about 200-250 mm and the pitch (h2) of the second helix is of about 400-500 mm.

17. Method for plastic waste thermolysis comprising the steps of

15 - continuously providing molten plastic waste to a thermolysis reactor (100) according to claims 1-16 at a temperature between 180 - 240 °C

- producing exhaust gases via at least one gas burner (150)

- guiding the exhaust gases on an outer surface of the thermolysis reactor (100) via at least one heating jacket (111)

20 - guiding the exhaust gases in the helical ducts of at least one of the first and second helices of the agitating device (130)

- continuously rotating the agitating device (130)

- heating the plastic waste to a temperature between 370 - 430 °C, thereby converting the waste plastic to gaseous form.

25 18. The method of claim 17 further comprising the step of automatically rejecting the carbon residues that are produced during thermolysis via a carbon rejection device (140).

30 19. The method of claims 17-18 comprising the steps of controlling the flow of the exhaust gases that are guided to the at least one heating jacket and to the agitating device (130).

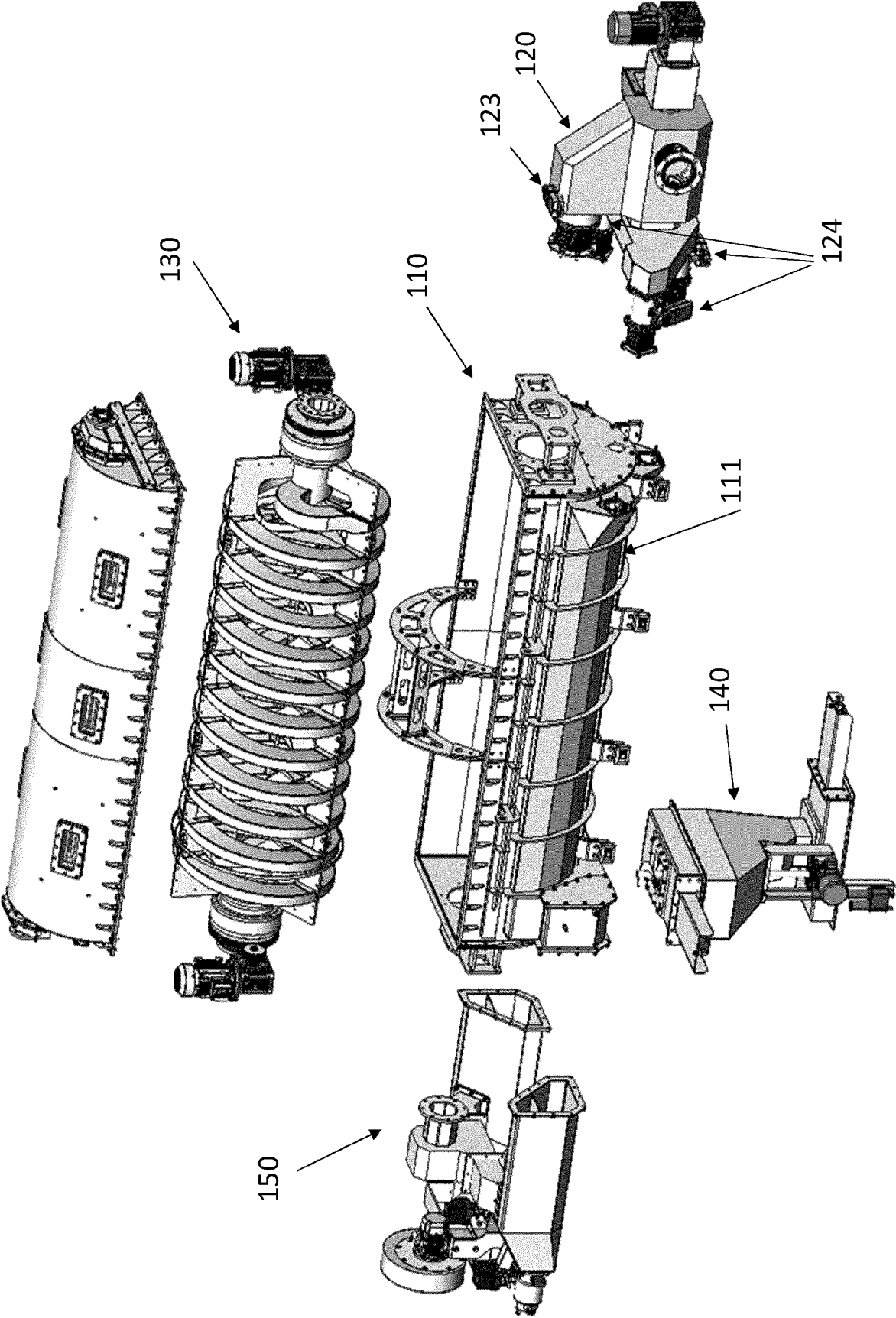


Figure 1

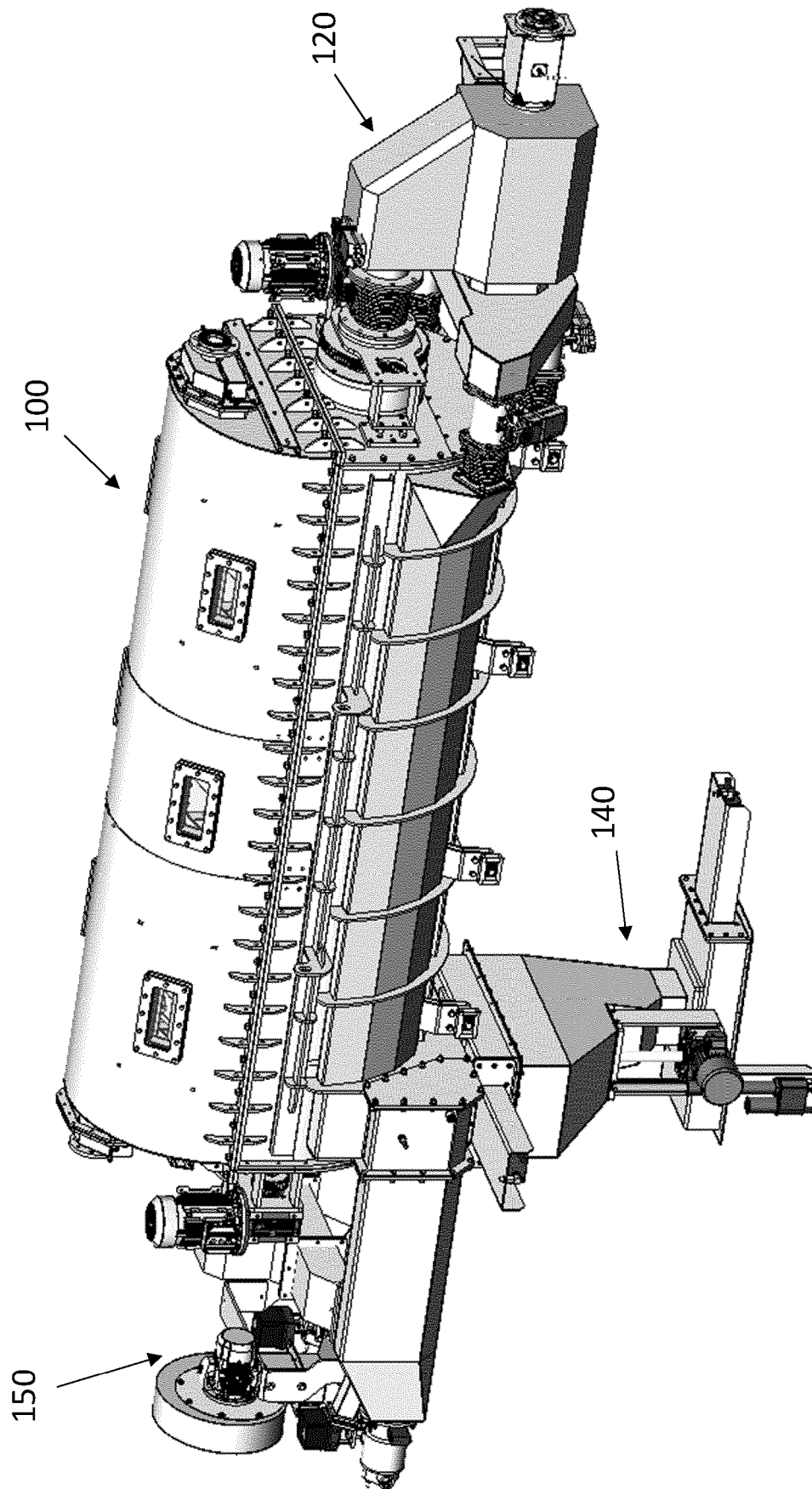


Figure 2

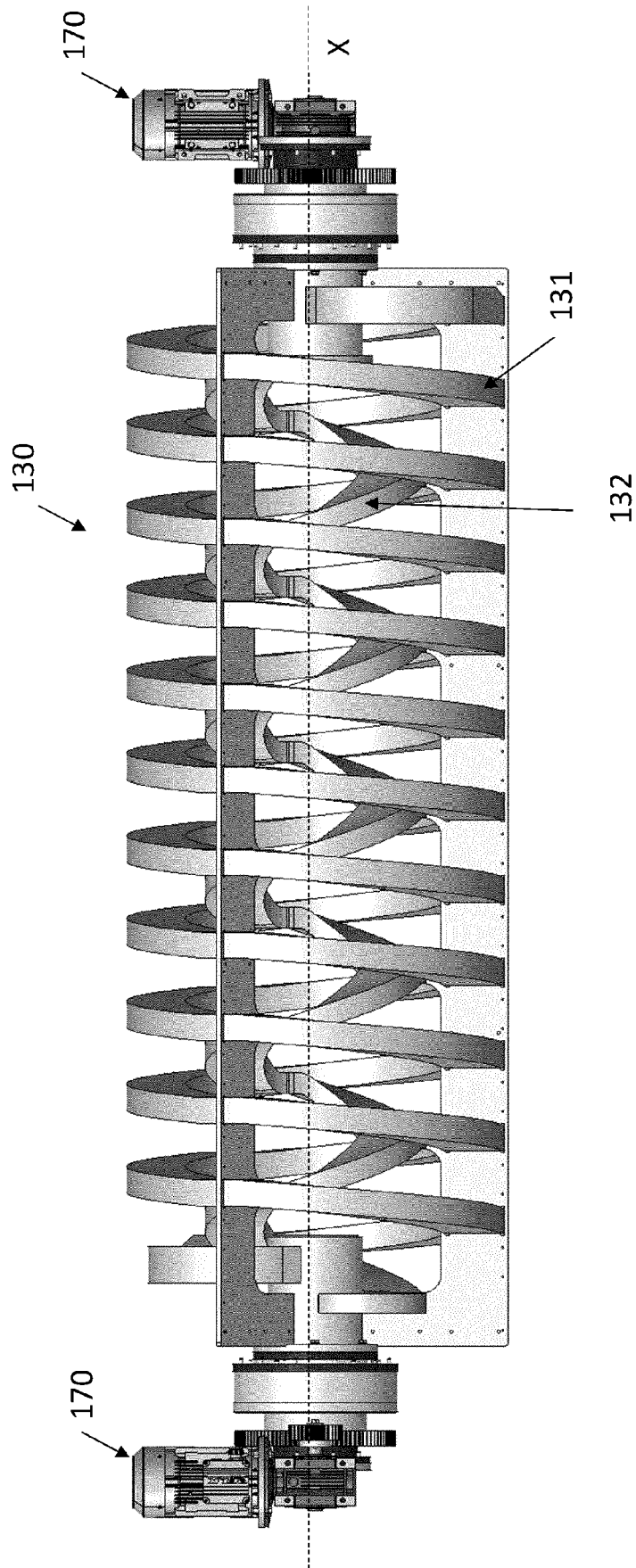


Figure 3

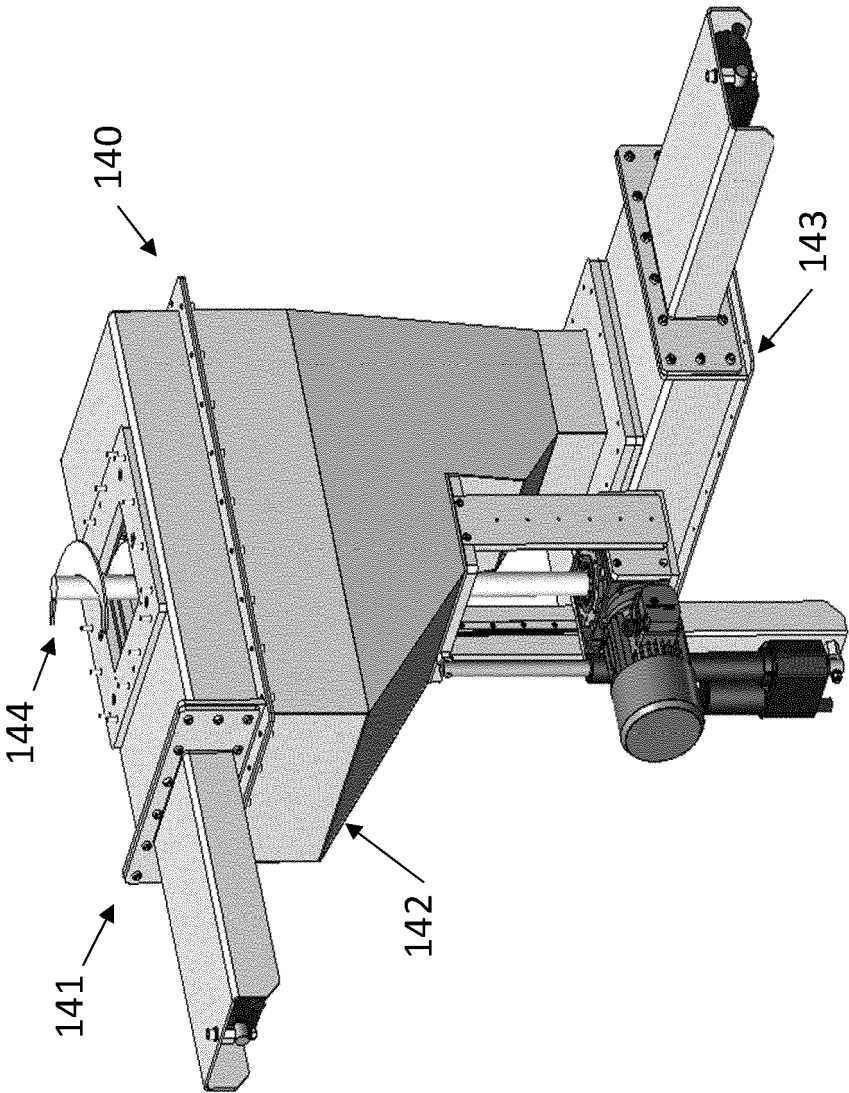


Figure 4

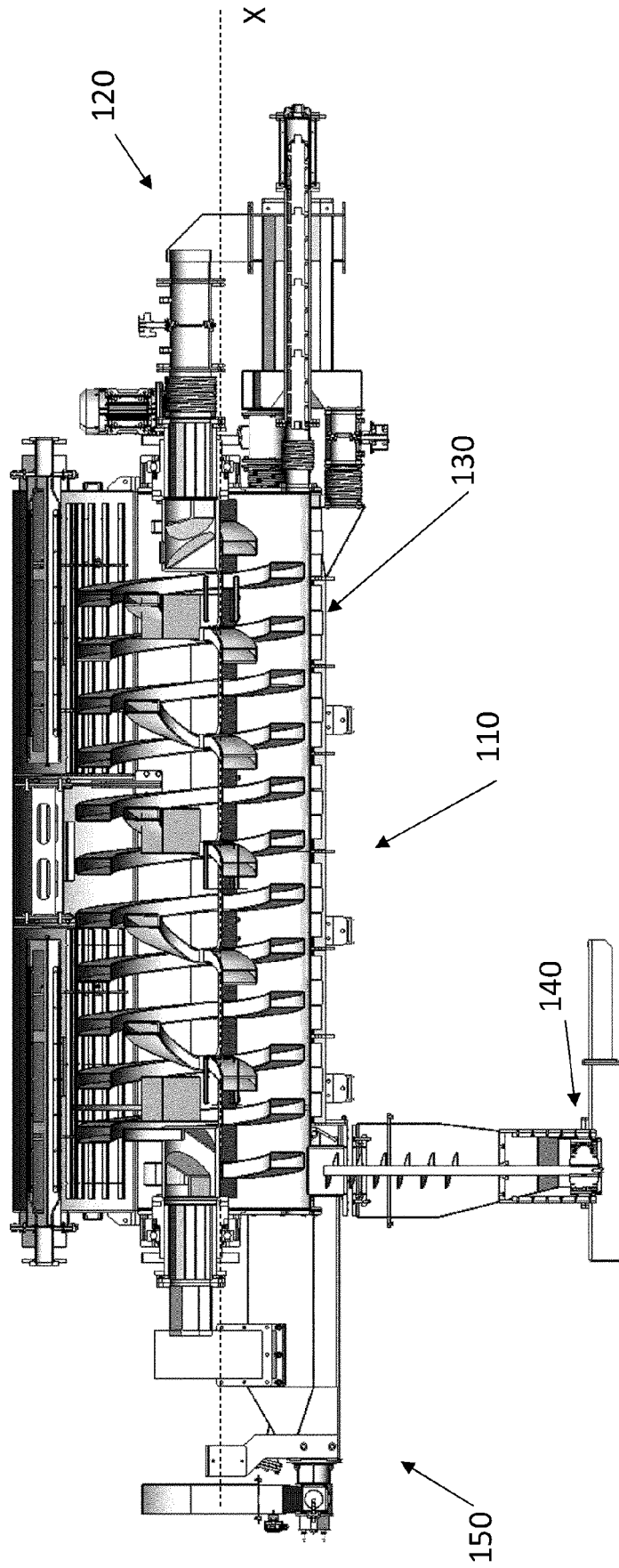


Figure 5

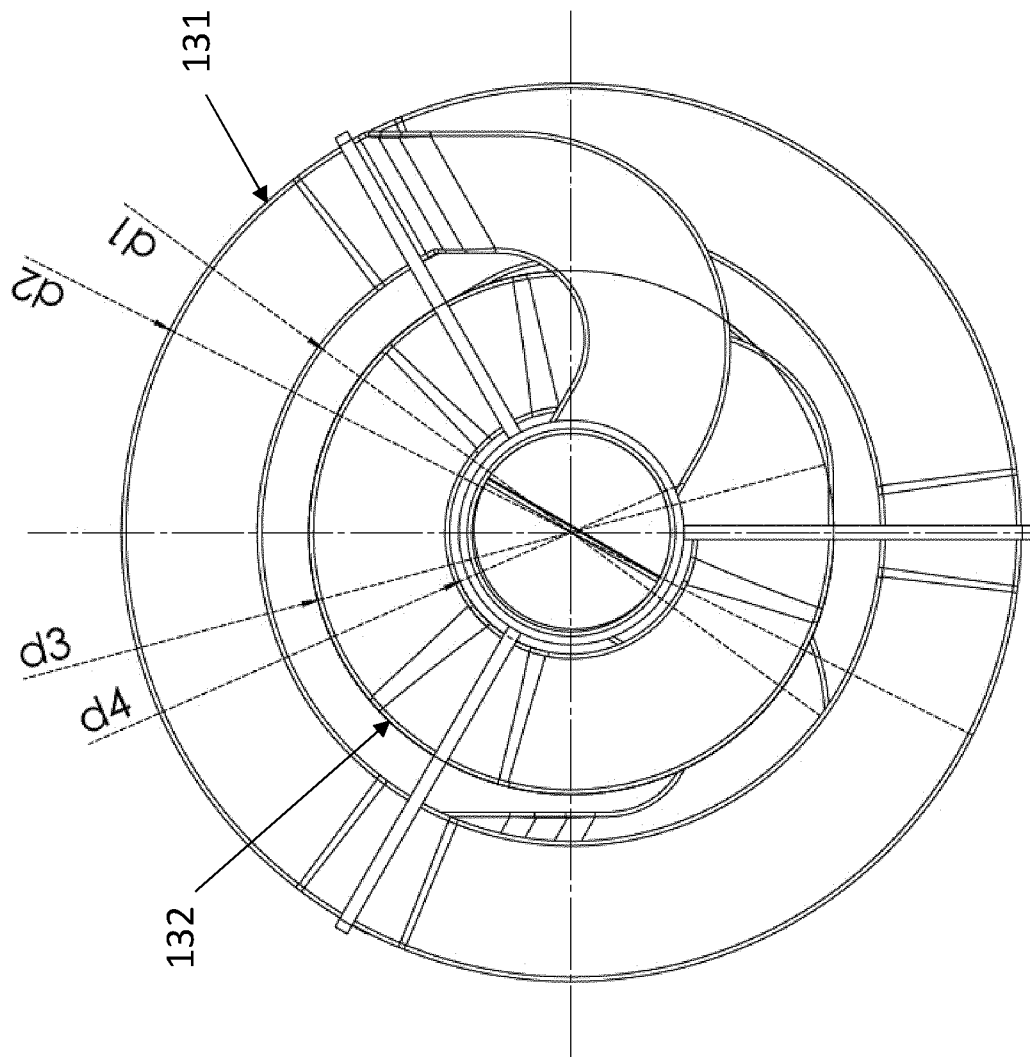


Figure 6

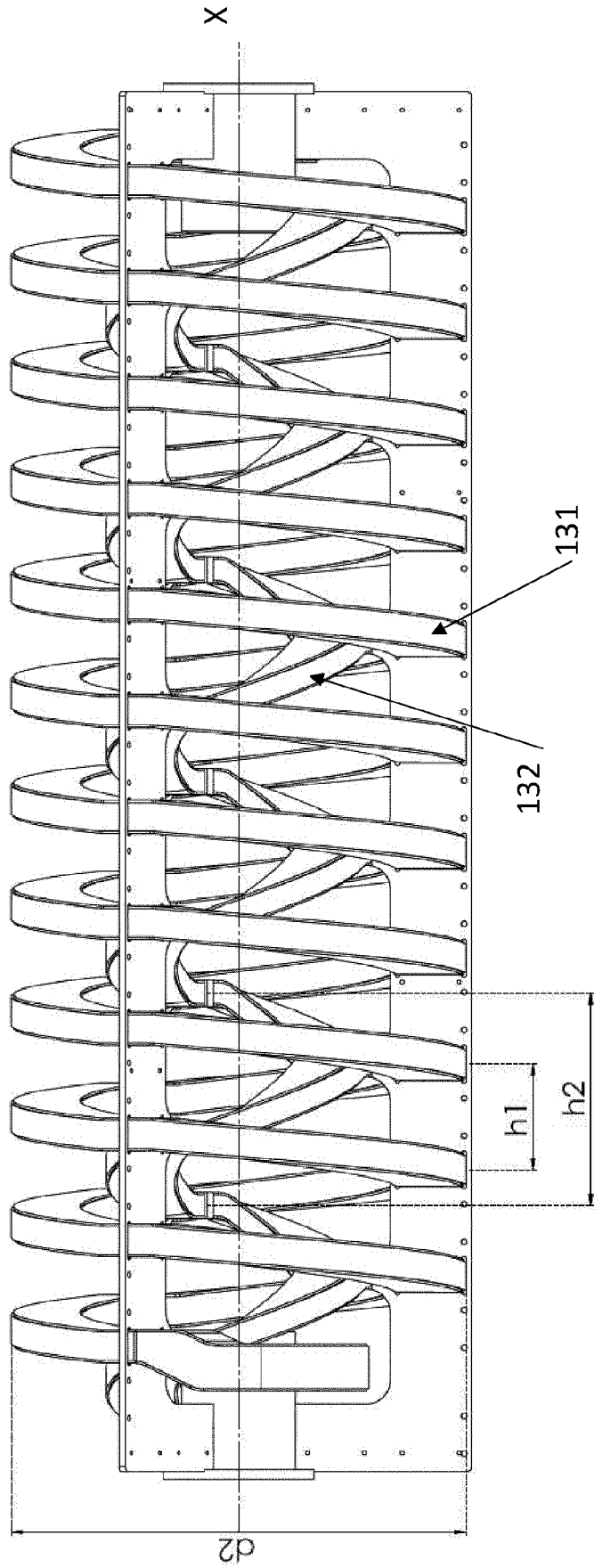


Figure 7



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Application Number

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