PROCESS, APPARATUS, CONTROLLER AND SYSTEM FOR PRODUCING PETROLEUM PRODUCTS

Cross Reference to Related Applications

[0001] This application claims the benefit of US Utility Application No. 15/473,569 entitled "Process, Apparatus, Controller and System for Producing Petroleum Products" filed March 29, 2017, and to U.S. Provisional Application No. 62/315,639 entitled "Pyrolysis Process, Apparatus, and System for Producing Petroleum Product" filed on March 30, 2016, the entire content of which are incorporated by reference herein.

Technical Field

[0002] The present invention relate generally to a process, apparatus, and system for producing petroleum products from feedstock containing polymers and an apparatus and system for carrying out the process. The present invention also relates to a controller for managing the process of producing petroleum products.

Background of the Invention

[0003] In the petroleum industry, commercially viable liquid products are produced from a variety of raw materials. These materials must be converted efficiently and with a consistent quality to meet market price and quality requirements. Plastic waste has traditionally been disposed of in a landfill or incinerated for the heat value due to the difficulty in economically sorting polymer types and consistently converting the material into fungible liquid products. Both the landfill and incineration pose environmental disadvantages and a low value and/or high cost solutions for this energy abundant feedstock.

[0004] A pyrolysis process is an example of a thermal decomposition process which has shown promise in efficiently converting the plastic waste streams into gases which can then be condensed into liquids for further processing into petroleum products and petrochemical products. Pyrolysis technologies have been unable to convert the full range of plastics in the waste stream which then requires that some level of sorting be performed in preparation of the feedstock, thus reducing the economic viability. In addition, due to changes in the plastic waste stream, many pyrolysis technologies have not been able to produce a consistent end product capable of being upgraded to petroleum products that can consistently meet required industry specifications. Such out of spec products require further processing which consumes great amounts of energy thus further reducing the economic viability.

[0005] While there are several methods currently available for generating petroleum products, there are drawbacks to such methods in terms of energy consumption, product yield and quality of the products produced.

Summary of the Invention

[0005a] According to a first aspect of the present invention, there is provided a process for producing a petroleum gas including the steps of: charging a feedstock comprising a polymer feedstock into a pyrolytic reactor vessel; said reactor having a screw for advancing said feedstock through said reactor; said reactor having a free volume of at least about 60% based on the amount of polymer feedstock in said reactor vessel; applying heat energy to said reactor vessel and converting said feedstock to molten material, pyrolyzing said molten polymeric material in an anaerobic operation in said free volume of said reactor vessel while advancing the molten material through said reactor vessel; cracking and reforming said molten material and forming said petroleum gas products in said reactor; and wherein said reactor does not rotate.

[0005b] According to a second aspect of the present invention, there is provided a reactor apparatus including: a reactor vessel; said reactor vessel capable of receiving a polymer feedstock; said reactor having a free volume of at least about 60% based upon the amount of said polymer feedstock in said reactor, said reactor having a screw for advancing said feedstock through said reactor; an outer shroud that surrounds the reactor vessel; an inner wall or a plurality thereof that extends between said outer shroud and said reactor vessel and defines a plurality of external heated fluid channels for a heat exchange medium.

[0006] Disclosed herein is a process for producing petroleum products that includes charging feedstock comprising mixed polymer materials into a reactor vessel of a reactor apparatus; applying heat to the reactor vessel while advancing the feedstock through the reactor apparatus in an anaerobic operation; controlling the energy input to the reactor vessel and controlling a temperature gradient within reactor vessel to produce a condensable petroleum gas product. The process for producing condensable petroleum gas products involves in situ chemical reactions that are managed to convert feedstock to solid inert residue, molten fluids and gases inside the reactor vessel and to produce condensable petroleum gas products which exit the reactor vessel.

[0007] Disclosed herein is a process for producing petroleum products that includes charging feedstock comprising mixed polymer materials into a reactor apparatus having a plurality of sequential reactor zones; applying heat energy to the reactor vessel while advancing the feedstock and products generated from the feedstock through the reactor apparatus; independently controlling the heat energy input to each of the plurality of sequential reactor zones and controlling a temperature gradient within each of the plurality of sequential reactor zones of the reactor apparatus.

[0008] Disclosed herein is a reactor apparatus for carrying out the thermal cracking of mixed polymer materials that includes a reactor vessel, an outer shroud surrounding the reactor vessel, defining a channel or plenum that conveys exhaust gas between the reactor vessel and the outer shroud of the reactor apparatus. In another example embodiment the reactor apparatus includes

an inner wall that extends between the reactor vessel and the outer shroud to define a first channel of a first reactor zone and a second channel or plenum of a second reactor zone for separately conveying exhaust gas between the reactor vessel and the outer shroud of the reactor apparatus.

[0009] Disclosed herein is a means for controlling the thermal cracking and recombination reactions in a reactor apparatus, including manual or automatic control of the mass flow rates and temperature profiles in each reactor zone.

[0010] Disclosed herein is a system for producing petroleum products that includes a reactor apparatus and a controller in communication with the reactor apparatus for controlling a process for producing petroleum products. The controller transmits and receives signals to the reactor apparatus to control several operating parameters of the reactor apparatus, the operating parameters includes the temperature profile within the reactor vessel along at least two axes.

[0011] Disclosed herein is a controller for controlling a process for producing petroleum products that includes a first control port for receiving a data from a first reactor zone and a first communications port for transmitting data to the first reactor zone of the reactor apparatus. The computing device includes a processing unit in communication with the first control port and the first communications port, and the processing unit includes control logic. The control logic is capable of receiving a data signal of the first control port that includes a temperature reading of a gas product in the first reactor zone and determining at least one of the heat input rate in the first reactor zone and the mass flow rate of at least one of the exhaust gas and product gas exiting the reactor apparatus in the first reactor zone.

Brief Description of the Drawings

[0012] The foregoing and other features of the present disclosure will become apparent to those skilled in the art to which the present disclosure relates upon reading the following description with reference to the accompanying drawings, in which:

[0013] FIG. 1 is a schematic flow diagram of a process for making petroleum products, according to an example of the present invention;

[0014] FIG. 2 is a cross-sectional schematic representation of a system for producing petroleum products, according to an example of the present invention;

[0015] FIG. 3 is a cross-sectional schematic representation of a system for producing petroleum products, according to another example of the present invention;

[0016] FIGS. 4a and 4b are flow diagrams illustrating methods of implementing a controller of a system for producing petroleum products, according to an example of the present invention;

CLAIMS

1. A process for producing a petroleum gas comprising the steps of:

charging a feedstock comprising a polymer feedstock into a pyrolytic reactor vessel;

said reactor having a screw for advancing said feedstock through said reactor;

said reactor having a free volume of at least about 60% based on the amount of polymer feedstock in said reactor vessel;

applying heat energy to said reactor vessel and converting said feedstock to molten material, pyrolyzing said molten polymeric material in an anaerobic operation in said free volume of said reactor vessel while advancing the molten material through said reactor vessel;

cracking and reforming said molten material and forming said petroleum gas products in said reactor; and

wherein said reactor does not rotate.

2. The process of claim 1, wherein the free volume of the reactor vessel is at least about 70%.

3. The process of claim 2, including an outer shroud that surrounds said reaction vessel; and an inner wall or plurality thereof that extends between said outer shroud and said reactor vessel and defines a plurality of fluid heating channels for a heat exchange medium, and wherein said process has no added catalyst.

4. The process of claim 1, wherein the process is semi-continuous or continuous process and wherein the composition of the feedstock varies during the process.

5. The process of claim 3, wherein said reactor comprises a plurality of sequential reactor zones along the horizontal axis of said reaction, controlling said heat energy and the temperature gradient both vertically and axially within said free volume of said reactor while thermally breaking said molten polymer materials by pyrolysis into gaseous molecules; and wherein the temperature gradient is the temperature differential between the temperature of the bottom

surface of the reactor vessel and the temperature of the petroleum gas product along the top portion of the reactor vessel and ranges from 50°C to 450°C.

6. The process of claim 3, wherein the energy distribution of each of said plurality of reactor zones is controlled by controlling a temperature gradient within each of the plurality of said reaction zones; wherein the temperature of the petroleum gas product exiting the reactor at the gas outlet port ranges from about 315°C to about 510°C; and wherein the pressure of the petroleum gas product exiting the reactor ranges from about 0 psig to about 50 psig.

7. The process of claim 3, wherein the fungible gas product obtained from the process ranges from 50% to 98% of the feedstock by weight.

8. The process of claim 5, wherein the plurality of the reactor zones includes a first reactor zone and a second reactor zone and heat energy is applied to the first reactor zone of the reactor vessel by a first heat source and heat energy is applied to the second reactor zone by a second heat source.

9. The process of claim 5, wherein the temperature gradient within each of the plurality of reactor zones is controlled by conveying exhaust gas in a first fluid channel along a first reactor zone of the reactor apparatus, and conveying exhaust gas in a second fluid channel along a second reactor zone of the reactor apparatus.

10. The process of claim 3, comprising collecting gaseous product, and wherein the gaseous products collected comprise at least about 50% by weight condensable hydrocarbons based on the weight of gaseous products.

11. The process of claim 3, wherein the condensable hydrocarbons produced comprises: from about 10% to about 60% by weight of each of a naphtha, a distillate and a fuel oil based on the weight of gaseous product.

12. The process of claim 3, wherein the composition of hydrocarbonaceous feedstock material varies from about 10 to about 70% polyethylene, from about 10% to about 70% polypropylene, from about 10% to about 30% polystyrene and from about 0% to about 30% other commonly use polymeric materials such as polyvinyl chloride, polyester, polycarbonate, polymethyl methacrylate, nylon and the like.

13. A reactor apparatus comprising:

a reactor vessel; said reactor vessel capable of receiving a polymer feedstock; said reactor having a free volume of at least about 60% based upon the amount of said polymer feedstock in said reactor, said reactor having a screw for advancing said feedstock through said reactor;

an outer shroud that surrounds the reactor vessel;

an inner wall or a plurality thereof that extends between said outer shroud and said reactor vessel and defines a plurality of external heated fluid channels for a heat exchange medium.

14. The reactor apparatus of claim 13, wherein

said reactor being capable of being heated through said shroud external fluid channels whereby said feedstock is converted to molten material;

said reactor capable of pyrolyzing said polymer feedstock molten material by cracking and reforming and producing petroleum gas products; and

said reactor having at least one product conduit for exiting said petroleum gas product stream through said reactor and said shroud; and

wherein said reactor apparatus is non-rotatable.

15. The reactor apparatus of claim 14, comprising a plurality of said inner walls that extend between said outer shroud and the reactor vessel.

16. The reactor apparatus of claim 15, wherein at least one said heated fluid channel containing a channel vent; and

wherein said polymer feed stock comprises polyethylene, polypropylene, polyester, acrylonitrile-butadiene-styrene (ABS) copolymers, polyamide, polyether, polycarbonate,

poly(oxide), poly(sulfide), polyarylate, polyetherketone, polyetherimide, polysulfone, polyurethane, polyvinyl alcohol, and polymers produced by polymerization of monomers comprising dienes, olefins, styrenes, acrylates, acrylonitriles, methacrylates, methacrylonitriles, polymers of diacids and diamines, lactams, vinyl halides, or vinyl esters and block copolymers thereof, and any combination thereof.

17. The reactor apparatus of claim16, wherein said at least one heated fluid channel vent comprises a flow control valve; and

wherein said free volume of said reactor is at least about 80%.

18. The reactor apparatus of claim 14, including a plurality of heat sources, at least one heat source being located in said fluid channel.

19. The reactor apparatus of claim 14, comprising temperature sensors in said product conduit.