PRODUCTION OF HYDROCARBON FUELS FROM WASTE PLASTIC

Field of the invention

This disclosure relates to the recycling of waste plastic and its transformation into hydrocarbon fuels and other hydrocarbon compounds by means of primary cracking and gas-phase catalytic hydrogenation, before fractional separation.

Background of the invention

Huge amounts of plastics end up in nature every year. The environmental consequences hereof have recently been realised. Not only does it destroy the esthetics of nature but it is realised that huge amount of microparticles are formed in particular in the oceans. These microparticles are taken up by fish and other organisms living in the ocean severely affecting their health.

At the same time, it is well known that the release of CO_2 to the atmosphere could beneficially be reduced as CO_2 is acknowledged to be a major factor in global heating. Advantageously, the extraction of petroleum products could be reduced in order to lower the CO_2 outlet. One way of limiting this extraction could be by re-using and/or recirculating material made from petroleum products.

Thus, it would be beneficial for the environment if plastic materials were to be recycled and the release of additional CO_2 into the atmosphere would be limited by lowering the extraction of petroleum products. This could be done for example by re-circulating the plastic material for producing hydrocarbon fuels from waste plastic.

Attempts have been made to re-cycle waste plastic materials in different processes to obtain different hydrocarbon fluids. However, an efficient process, preferably self-sufficient in terms of energy and directed for an optimal production of specific hydrocarbon fuels is still needed.

Brief summary

An object of the present disclosure relates to a method and a system for re-using waste plastic to produce liquid fuel, gas and hydrocarbon compounds.

It is a further object of the present disclosure to re-use the energy obtained in the method for the method to be self-sufficient in terms of energy, for the method only to use a limited amount of extracted petroleum products thereby reducing potential human-produced CO_2 emissions.

These objects are achieved according to the aspects, embodiments and examples of the present disclosure as described herein.

The disclosure provides a method for producing fuel and additional hydrocarbons from waste plastic, comprising the steps of

- providing at least one plastic material;
- exposing said at least one plastic material to a primary cracking to obtain a first hydrocarbon fluid; said first hydrocarbon fluid being a gas;
- exposing said first hydrocarbon gas to a catalytic hydrogenation to obtain a second hydrocarbon fluid;
- fractional separation of said second hydrocarbon fluid to obtain at least one final product.

In one aspect of the disclosure, a method for producing fuel and additional hydrocarbons from waste plastic is provided, comprising the steps of

- providing at least one plastic material;
- exposing said at least one plastic material to anaerobic thermal cracking to obtain a first hydrocarbon fluid; said first hydrocarbon fluid being a gas;
- exposing said first hydrocarbon gas to a catalytic hydrogenation to obtain a second hydrocarbon fluid;
- fractional separation of said second hydrocarbon fluid to obtain at least one final product;

wherein the method further comprises

- - a step of condensation after said step of catalytic hydrogenation, wherein said second hydrocarbon fluid is obtained via at least said steps of catalytic hydrogenation and condensation and wherein said second hydrocarbon fluid is a multi-phase hydrocarbon fluid; and

- a step of separation after said step of condensation, wherein said second hydrocarbon fluid is obtained at least via said steps of catalytic hydrogenation, condensation and separation and wherein said second hydrocarbon fluid is a first hydrocarbon liquid obtained from said multi-phase hydrocarbon fluid during separation.

In one example, the method further comprises a step of condensation after said step of catalytic hydrogenation, wherein said second hydrocarbon fluid is obtained via at least said steps of catalytic hydrogenation and condensation and wherein said second hydrocarbon fluid is a multi-phase hydrocarbon fluid.

In a further example, the method further comprises a step of separation after said step of condensation, wherein said second hydrocarbon fluid is obtained at least via said steps of catalytic hydrogenation, condensation and separation and wherein said second hydrocarbon fluid is a first hydrocarbon liquid obtained from said multi-phase hydrocarbon fluid during separation.

In a still further example, the method according to any of the preceding items further comprising a step of pre-hydrogenation catalytic cracking performed prior to the step of catalytic hydrogenation, and wherein said first hydrocarbon fluid is obtained at least via said steps of primary cracking and pre-hydrogenation catalytic cracking.

In a still further example, the method further comprises a step of post-hydrogenation catalytic cracking performed after the step of catalytic hydrogenation and wherein said second hydrocarbon fluid is obtained at least via said steps of catalytic hydrogenation and post-hydrogenation catalytic cracking.

In a still further example, primary cracking of the method is performed by an anaerobic thermal cracking reactor.

In a still further example, the method does not include any of the following steps neither alone nor in combination: hydrocracking, hydroconversion, and hydrodealkylation. In an even further example, the method includes a step of catalytic hydrogenation with the proviso that the catalytic hydrogenation is not hydrocracking, hydroconversion, and/or hydrodealkylation.

In a still further example, the catalytic hydrogenation is performed at a pressure range of 0.1 to 10 bar, preferably in the range of 0.7 to 2 bar, such as around 1 bar.

In a still further example, the catalytic hydrogenation is performed at a temperature range of 300°C to 550°C, preferably between 380°C and 460°C, such as around 420°C .

In a still further example, the method further comprises a step of circulating of said second hydrocarbon fluid to a holding tank prior to fractional separation.

In a still further example, the heavy fraction is recycled to the step of primary cracking, catalytic cracking and/or catalytic hydrogenation or to said holding tank.

In a still further example, the heavy fraction is exposed to a step of heavy fraction cracking before being recycled to the step of primary cracking, catalytic cracking and/or catalytic hydrogenation or to said holding tank.

The disclosure also provides a waste recycling system for recycling waste plastic into fluid hydrocarbon compounds comprising

- a primary cracking reactor capable of receiving at least one plastic material and producing a first hydrocarbon fluid from said at least one plastic material by a primary cracking, said first hydrocarbon fluid being a gas;
- a catalytic hydrogenation reactor capable of receiving said first hydrocarbon fluid and producing a second hydrocarbon fluid by catalytic hydrogenation,
- and a fractional separator capable of fractional separation of said second hydrocarbon fluid to obtain at least one final product,

where said primary cracking reactor is in fluid connection with said catalytic hydrogenation reactor and said catalytic hydrogenation reactor is in fluid connection with said fractional separator.

In a further aspect according to the disclosure, a waste recycling system for recycling waste plastic into fluid hydrocarbon compounds is provided, comprising

- an anaerobic thermal cracking reactor capable of receiving at least one plastic material and producing a first hydrocarbon fluid from said at least one plastic material by a primary cracking, said first hydrocarbon fluid being a gas;
- a catalytic hydrogenation reactor capable of receiving said first hydrocarbon fluid and producing a second hydrocarbon fluid by catalytic hydrogenation,
- and a fractional separator capable of fractional separation of said second hydrocarbon fluid to obtain at least one final product,

where said primary cracking reactor is in fluid connection with said catalytic hydrogenation reactor and said catalytic hydrogenation reactor is in fluid connection with said fractional separator;

wherein said system further comprises

- a condenser for producing said second hydrocarbon fluid together with said catalytic hydrogenation reactor and resulting in said second hydrocarbon fluid being a multi-phase hydrocarbon fluid, wherein said catalytic hydrogenation reactor is further fluidly connected with said fractional separator through said condenser; and

- a post-condensation separator for separating said multi-phase hydrocarbon fluid to provide a first hydrocarbon liquid and a first non-condensable hydrocarbon gas, and wherein said condenser is further fluidly connected with said fractional separator through said post-condensation separator.

In one example, the system further comprises a condenser for producing said second hydrocarbon fluid together with said catalytic hydrogenation reactor and resulting in said second hydrocarbon fluid being a multi-phase hydrocarbon fluid, and wherein said catalytic hydrogenation reactor is further fluidly connected with said fractional separator through said condenser.

In a further example, the system further comprises a post-condensation separator for separating said multi-phase hydrocarbon fluid to provide a first hydrocarbon liquid and a first non-condensable hydrocarbon gas, and wherein said condenser is further fluidly connected with said fractional separator through said post-condensation separator.

In a still further example, the system further comprises a pre-hydrogenation catalytic cracking reactor, wherein said primary cracking reactor is further fluidly connected with said catalytic hydrogenation reactor through said pre-hydrogenation catalytic cracking reactor.

In a still further example, the system further comprises a post-hydrogenation catalytic cracking reactor, wherein said catalytic hydrogenation reactor is further fluidly connected with said fractional separator through said post-hydrogenation catalytic cracking reactor.

In a still further example, the system further comprises a holding tank for storing the second hydrocarbon fluid prior to fractional separation, where said catalytic hydrogenation reactor is fluidly connected with the fractional separator at least via said holding tank.

In a still further example, the system further comprises a gas burner for providing heat to said primary cracking reactor, said gas burner is fluidly connected with said post-condensation separator.

In a still further example, the system further comprises a heavy fraction cracking reactor, said heavy fraction cracking reactor being in fluidly connection with said fractional separator for receiving a heavy fraction obtained from the fractional separation process and wherein said heavy fraction cracking reactor is further fluidly connected with said primary cracking reactor, said pre-hydrogenation catalytic cracking reactor, said post-hydrogenation catalytic cracking reactor and/or said catalytic hydrogenation reactor.

In a still further example, the system further comprises a post-fractional separation condenser, a non-condensable gas separator and a gas burner, said post-fractional separation condenser being in fluidly connection with said fractional separator for receiving a light fraction obtained from the fractional separation process and wherein said post-fractional separation condenser is further fluidly connected with said non-condensable gas separator for separating a light non-condensable hydrocarbon gas; said non-condensable gas separator being further fluidly connected with said gas burner.

In a further aspect of the invention, the use of a system as described herein or a method as described herein for producing fuel and additional hydrocarbons from waste plastic is provided.

In a further use, the fuel is diesel.

Claims

1. A method for producing fuel and additional hydrocarbons from waste plastic comprising the steps of

- providing at least one plastic material;
- exposing said at least one plastic material to anaerobic thermal cracking to obtain a first hydrocarbon fluid; said first hydrocarbon fluid being a gas;
- exposing said first hydrocarbon gas to a catalytic hydrogenation to obtain a second hydrocarbon fluid;
- fractional separation of said second hydrocarbon fluid to obtain at least one final product;

wherein the method further comprises

- - a step of condensation after said step of catalytic hydrogenation, wherein said second hydrocarbon fluid is obtained via at least said steps of catalytic hydrogenation and condensation and wherein said second hydrocarbon fluid is a multi-phase hydrocarbon fluid; and
- a step of separation after said step of condensation, wherein said second hydrocarbon fluid is obtained at least via said steps of catalytic hydrogenation, condensation and separation and wherein said second hydrocarbon fluid is a first hydrocarbon liquid obtained from said multi-phase hydrocarbon fluid during separation.

2. The method according to any of the preceding claims further comprising a step of pre-hydrogenation catalytic cracking performed prior to the step of catalytic hydrogenation, and wherein said first hydrocarbon fluid is obtained at least via said steps of primary cracking and pre-hydrogenation catalytic cracking.

3. The method according to any of the preceding claims further comprising a step of post-hydrogenation catalytic cracking performed after the step of catalytic hydrogenation and wherein said second hydrocarbon fluid is obtained at least via said steps of catalytic hydrogenation and post-hydrogenation catalytic cracking.

4. The method according to claim 1 wherein said separation further results in the formation of a first non-condensable hydrocarbon gas and wherein at least a part

of said first non-condensable hydrocarbon gas is recirculated to and burnt in a gas burner to provide heat to said primary cracking.

5. The method according to any of the preceding claims, wherein three final products are obtained from said fractional separation step, these products being a light fraction such as mainly C6 to C10; a medium fraction such as mainly C11 to C20 and a heavy fraction such as mainly C21 and above.

6. The method according to any of the preceding claims, wherein said catalytic hydrogenation is performed at operating temperatures between 150-280°C, preferably between 190-230°C, such as around 200°C.

7. The method according to any of the preceding claims, wherein said catalytic hydrogenation is performed at a pressure range of 0.1 to 10 bar, preferably a range of 0.5 to 5 bar, like in the range of 0.7 to 2 bar, such as in the range of 0.9 to 1.1 bar, preferably around 1 bar.

8. The method according to any one of the claims 5-7, wherein said heavy fraction is recycled to the step of primary cracking, catalytic cracking and/or catalytic hydrogenation or to said holding tank.

9. The method according to claim 8, wherein said heavy fraction is exposed to a step of heavy fraction cracking before being recycled to the step of primary cracking, catalytic cracking and/or catalytic hydrogenation or to said holding tank.

10. A waste recycling system for recycling waste plastic into fluid hydrocarbon compounds comprising

- an anaerobic thermal cracking reactor capable of receiving at least one plastic material and producing a first hydrocarbon fluid from said at least one plastic material by a primary cracking, said first hydrocarbon fluid being a gas;
- a catalytic hydrogenation reactor capable of receiving said first hydrocarbon fluid and producing a second hydrocarbon fluid by catalytic hydrogenation,

- and a fractional separator capable of fractional separation of said second hydrocarbon fluid to obtain at least one final product,

where said primary cracking reactor is in fluid connection with said catalytic hydrogenation reactor and said catalytic hydrogenation reactor is in fluid connection with said fractional separator; wherein said system further comprises

- a condenser for producing said second hydrocarbon fluid together with said catalytic hydrogenation reactor and resulting in said second hydrocarbon fluid being a multi-phase hydrocarbon fluid, wherein said catalytic hydrogenation reactor is further fluidly connected with said fractional separator through said condenser; and
- a post-condensation separator for separating said multi-phase hydrocarbon fluid to provide a first hydrocarbon liquid and a first non-condensable hydrocarbon gas, and wherein said condenser is further fluidly connected with said fractional separator through said post-condensation separator.

11. The system according to claim 10, wherein said system further comprises a pre-hydrogenation catalytic cracking reactor, wherein said primary cracking reactor is further fluidly connected with said catalytic hydrogenation reactor through said pre-hydrogenation catalytic cracking reactor.

12. The system according to any of the claims 10-11, wherein said system further comprises a post-hydrogenation catalytic cracking reactor, wherein said catalytic hydrogenation reactor is further fluidly connected with said fractional separator through said post-hydrogenation catalytic cracking reactor.

13. The system according to any one of the claims 10-12, wherein said system further comprises a gas burner for providing heat to said primary cracking reactor, said gas burner is fluidly connected with said post-condensation separator.

14. The system according to any one of the claims 10-13, wherein the system further comprises a heavy fraction cracking reactor, said heavy fraction cracking reactor being in fluidly connection with said fractional separator for receiving a heavy fraction obtained from the fractional separation process and wherein said heavy fraction cracking reactor is further fluidly connected with said primary

cracking reactor, said pre-hydrogenation catalytic cracking reactor, said post-hydrogenation catalytic cracking reactor and/or said catalytic hydrogenation reactor.

15. Use of a system as described in any of the claims 10-14 or a method as described in any of the claims 1-9 for producing fuel and additional hydrocarbons from waste plastic.

16. Use according to claim 15, wherein said fuel is Diesel.