METHODS AND SYSTEMS FOR LIQUEFACTION OF CARBONACEOUS MATERIALS

Cross-reference to Related Applications

This application claims priority to U.S. Provisional Patent Application No. 63/227,406, filed July 30, 2021, which is incorporated herein by reference.

Field of the Invention

This application relates to liquefaction of carbonaceous materials, including methods and systems for liquefaction.

Background

Liquefaction is a process that may be used to convert carbonaceous materials, such as coal, to one or more liquids, which may be used as fuels or petrochemicals.

Coal liquefaction has been performed in several ways. Some methods use steam and oxygen to gasify coal to produce synthesis gas, which is then reacted with a catalyst in a Fischer-Tropsch process to convert the synthesis gas into one or more liquids, which may include a range of useful hydrocarbons. Some methods contact pulverized coal with hydrogen and a catalyst in the presence of a solvent at high pressure and temperature in order to convert the pulverized coal into one or more liquids, which may be used as fuels.

These methods, however, typically are energy intensive, inefficient, environmentally harmful, or a combination thereof.

Summary

Provided herein are methods and systems for liquefaction that overcome one or more of the foregoing disadvantages, including methods and systems that rely on heat generated by electromagnetic radiation.

Methods of liquefaction are provided in the present disclosure. In some examples, the methods include providing a hydrogen donor; and contacting a solid carbonaceous material and the hydrogen donor to convert at least a portion of the solid carbonaceous material to a product. The hydrogen donor may have a temperature of at least 300 °C. The contacting of the solid carbonaceous material and the hydrogen donor may occur at a pressure greater than ambient pressure, such as a pressure that is equal to or greater than the critical pressure of the hydrogen donor.

In one aspect, the present disclosure provides a method of liquefaction, the method comprising:

providing a hydrogen donor; and

contacting a solid carbonaceous material and the hydrogen donor to convert at least a portion of the solid carbonaceous material to a product;

wherein the providing of the hydrogen donor comprises -

(a) irradiating a susceptor material with electromagnetic energy to provide a heated susceptor material, and

(b) contacting the hydrogen donor and the heated susceptor material to heat the hydrogen donor to a temperature of at least 300 °C;

wherein the susceptor material and the heated susceptor material do not contact the solid carbonaceous material, and wherein the susceptor material and the heated susceptor material do not contact the product.

Systems are provided in the present disclosure, including systems that may be used for liquefaction. In some examples, the systems include a reactor; a hydrogen donor feeder; and a product liquid collection reservoir. The hydrogen donor feeder and the product liquid collection reservoir may be in fluid communication with the reactor. The reactor may be configured to receive a carbonaceous material from a carbonaceous material feeder. The hydrogen donor feeder may be configured to provide to the reactor a hydrogen donor, such as a hydrogen donor having a temperature of at least 300 °C.

In another aspect, the present disclosure provides a system comprising:

a reactor;

a hydrogen donor feeder; and

a product liquid collection reservoir;

wherein the hydrogen donor feeder and the product liquid collection reservoir are in fluid communication with the reactor,

wherein the reactor is configured to receive a carbonaceous material from a carbonaceous material feeder; and

wherein the hydrogen donor feeder is configured to provide to the reactor a hydrogen donor.

The systems also may include a circulation conduit configured to remove from the reactor and then return to the reactor at least a portion of the reactor's contents. The systems also may include a condenser; and a product condensate collection reservoir. The condenser may be in fluid communication with the reactor, and the product condensate collection reservoir may be in fluid communication with the condenser. The systems also may include a reactor heater. The systems also may include one or more process gas feeders, such as a first process gas feeder that may be in fluid communication with the reactor, the carbonaceous material feeder, the product liquid collection reservoir, or a combination thereof; and a second process gas feeder, which may be in fluid communication with the product liquid collection reservoir.

Methods of liquefaction using the systems described herein are provided in the present disclosure. In some examples, the methods include providing any of the systems described herein; optionally heating the reactor with the reactor heater to a pre-heat reactor temperature of at least 300 °C; disposing a process gas, such as an inert gas, in the reactor from the first process gas feeder to pressurize the reactor; disposing the hydrogen donor in the reactor; disposing a carbonaceous material from the carbonaceous material feeder into the reactor to contact the carbonaceous material and the hydrogen donor in the reactor to produce a product; collecting a product condensate in the product condensate collection reservoir; and collecting a product liquid in the product liquid collection reservoir.

In another aspect, the present disclosure provides a method of liquefaction, the method comprising:

providing the system as described herein;

optionally heating the reactor with the reactor heater to a pre-heat reactor temperature of at least 300 °C;

optionally disposing a process gas in the reactor from the first process gas feeder to pressurize the reactor to a pressure greater than atmospheric pressure;

disposing the hydrogen donor in the reactor;

optionally maintaining in the reactor the pressure greater than atmospheric pressure;

disposing the carbonaceous material from the carbonaceous material feeder into the reactor to contact the carbonaceous material and the hydrogen donor in the reactor to convert at least a portion of the carbonaceous material to a product;

collecting a product condensate in the product condensate collection reservoir; and

collecting a product liquid in the product liquid collection reservoir.

The reactor may be pressurized to any pressure greater than atmospheric pressure. For example, the reactor may be pressurized to a pressure equal to or greater than the critical pressure of a hydrogen donor in the hydrogen donor feeder, and the methods may include maintaining in the reactor the pressure greater than atmospheric pressure, such as the pressure equal to or greater than the critical pressure of the hydrogen donor, prior to the collecting of the product condensate and the product liquid.