CLAIMS

1. A method for upgrading pyrolysis oil, the method comprising:

combining a heavy pyrolysis oil and a diluent to produce a pyrolysis oil feed, wherein:

the heavy pyrolysis oil comprises greater than or equal to 30 wt.% multi-ring aromatic compounds having boiling point temperatures greater than or equal to 360 °C; and

the diluent comprises a light pyrolysis oil having a density less than 0.98 grams per cubic centimeter;

passing the pyrolysis oil feed to a fixed-bed reactor comprising a hydrocracking catalyst comprising pellets having a particle size greater than or equal to 0.1 millimeter, wherein the hydrocracking catalyst comprises:

a supported metal oxide catalyst comprising molybdenum oxide and nickel oxide supported on a catalyst support material comprising a large-pore alumina having a total pore volume of from 0.8 centimeters cubed per gram to 1.1 centimeters cubed per gram; and

contacting the pyrolysis oil feed with hydrogen in the presence of the hydrocracking catalyst at reaction conditions in the fixed-bed reactor, wherein the contacting the pyrolysis oil feed with the hydrogen in the presence of the hydrocracking catalyst causes at least a portion of the pyrolysis oil to react to form a reaction effluent comprising a concentration of aromatic compounds having boiling point temperatures of from 50 °C to 360 °C greater than the pyrolysis oil feed.

2. The method of claim 1, wherein the supported metal oxide catalyst comprises from 3 wt.% to 7 wt.% nickel oxide and from 13 wt.% to 17 wt.% molybdenum oxide based on the total weight of the supported metal oxide catalyst.

3. The method of claim 1, wherein the supported metal oxide catalyst comprises from 1 wt.% to 8 wt.% phosphorus compounds based on the total weight of the supported metal oxide catalyst.

4. The method of claim 1, wherein the catalyst support material comprises from 53 wt.% to 68 wt.% of the large-pore alumina and from 15 wt.% to 25 wt.% of a binder, based on the total weight of the catalyst support material.

5. The method of claim 1, wherein the large-pore alumina has a BET surface area less than 200 meters squared per gram, an average pore radius of greater than or equal to 10 nanometers, or both.

6. The method of claim 1, wherein the pyrolysis oil feed comprises from 75 wt. % to 85 wt. % of the heavy pyrolysis oil and from 15 wt. % to 25 wt. % of the light pyrolysis oil as the diluent, based on the total weight of the pyrolysis oil feed.

7. The method of claim 1, further comprising:

steam cracking a naphtha stream in a steam cracking unit to produce a naphtha steam cracker effluent;

separating the naphtha steam cracker effluent in a naphtha steam cracker effluent separator to produce one or more product streams and the heavy pyrolysis oil; and

passing the heavy pyrolysis oil from the naphtha steam cracker effluent separator to the fixed-bed reactor as at least a portion of the pyrolysis oil feed.

8. The method of claim 1, further comprising:

steam cracking a hydrocarbon gas in a hydrocarbon gas steam cracking unit to produce a gas steam cracker effluent;

separating the gas steam cracker effluent in a gas steam cracker effluent separator to produce one or more product streams and the light pyrolysis oil; and

passing the light pyrolysis oil from the gas steam cracker effluent separator to the fixed-bed reactor as at least a portion of the pyrolysis oil feed.

9. The method of claim 1, wherein the contacting comprises contacting the pyrolysis oil feed with the hydrogen in the presence of the hydrocracking catalyst in the fixed-bed reactor at a temperature of from 300 °C to 500 °C, a pressure of from 1 MPa to 20 MPa, a gas hourly space velocity of from 200 h^{-1} to 1500 h^{-1}, and a liquid hourly space velocity of 0.1 h^{-1} to 1.2 h^{-1}.

10. The method of claim 1, wherein the diluent further comprises benzene, toluene, xylene, or combinations thereof.

11. A system for upgrading a pyrolysis oil feed, the system comprising:

a pyrolysis oil feed stream comprising:

a heavy pyrolysis oil having greater than or equal to 30 wt.% multi-ring aromatic compounds having boiling point temperatures greater than or equal to 360 °C; and

a diluent comprising a light pyrolysis oil having a density less than 0.98 grams per cubic centimeter; and

a fixed-bed reactor comprising a hydrocracking catalyst, wherein:

the hydrocracking catalyst comprises:

a mixed metal oxide catalyst comprising a binder and a plurality of mixed metal oxide particles, each of the mixed metal oxide particles comprising iron oxide (Fe_2O_3), zirconium oxide (ZrO_2), cerium oxide (CeO_2), and alumina (Al_2O_3); or

a supported metal oxide catalyst comprising molybdenum oxide and nickel oxide supported on a catalyst support material comprising a large-pore alumina having a total pore volume of from 0.8 centimeters cubed per gram to 1.1 centimeters cubed per gram; and

the fixed-bed reactor is operable to contact the pyrolysis oil feed with hydrogen in the presence of the hydrocracking catalyst to produce a reactor effluent comprising a greater concentration of aromatic compounds having boiling point temperatures of from 50 °C to 360 °C compared to the pyrolysis oil feed; and

a hydrocarbon gas steam cracking system upstream of the fixed-bed reactor, the hydrocarbon gas steam cracking system comprising:

a gas steam cracking unit operable to steam crack a hydrocarbon gas to produce a gas steam cracker effluent; and

a gas steam cracker effluent separator operable to separate the gas steam cracker effluent to produce one or more steam cracking product streams and a light pyrolysis oil.

12. The system of claim 11, further comprising a naphtha steam cracking system upstream of the fixed-bed reactor, the naphtha steam cracking system comprising:

a naphtha steam cracking unit operable to steam crack a naphtha stream to produce a naphtha steam cracker effluent; and

a naphtha steam cracker effluent separator operable to separate the naphtha steam cracker effluent to produce one or more steam cracking product streams and the heavy pyrolysis oil.

13. The system of claim 12, wherein the naphtha steam cracker effluent separator is fluidly coupled to an inlet of the fixed-bed reactor to pass the heavy pyrolysis oil directly to the fixed-bed reactor as at least a portion of the pyrolysis oil feed.

14. The system of claim 12, wherein the gas steam cracker effluent separator is fluidly coupled to an inlet of the fixed-bed reactor to pass the light pyrolysis oil directly to the fixed-bed reactor as at least a portion of the diluent in the pyrolysis oil feed.

15. A method for upgrading pyrolysis oil, the method comprising:

combining a heavy pyrolysis oil and a diluent to produce a pyrolysis oil feed, wherein:

the heavy pyrolysis oil comprises greater than or equal to 30 wt.% multi-ring aromatic compounds having boiling point temperatures greater than or equal to 360 °C; and

the diluent comprises a light pyrolysis oil having a density less than 0.98 grams per cubic centimeter;

passing the pyrolysis oil feed to a fixed-bed reactor comprising a hydrocracking catalyst comprising pellets having a particle size greater than or equal to 0.1 millimeter, wherein the hydrocracking catalyst comprises:

a mixed metal oxide catalyst comprising a binder and a plurality of mixed metal oxide particles, each of the mixed metal oxide particles comprising iron oxide (Fe_2O_3), zirconium oxide (ZrO_2), cerium oxide (CeO_2), and alumina (Al_2O_3); or

a supported metal oxide catalyst comprising molybdenum oxide and nickel oxide supported on a catalyst support material comprising a large-pore alumina having a total pore volume of from 0.8 centimeters cubed per gram to 1.1 centimeters cubed per gram;

contacting the pyrolysis oil feed with hydrogen in the presence of the hydrocracking catalyst at reaction conditions in the fixed-bed reactor, wherein the contacting the pyrolysis oil

feed with the hydrogen in the presence of the hydrocracking catalyst causes at least a portion of the pyrolysis oil to react to form a reaction effluent comprising a concentration of aromatic compounds having boiling point temperatures of from 50 °C to 360 °C greater than the pyrolysis oil feed;

steam cracking a naphtha stream in a steam cracking unit to produce a naphtha steam cracker effluent;

separating the naphtha steam cracker effluent in a naphtha steam cracker effluent separator to produce one or more product streams and the heavy pyrolysis oil; and

passing the heavy pyrolysis oil from the naphtha steam cracker effluent separator to the fixed-bed reactor as at least a portion of the pyrolysis oil feed.