seasonal and the quality of pitch may not meet local specifications. The pitch could be gasified, but costs are generally prohibitive. Pitch is therefore not a desired byproduct.

SUMMARY OF THE CLAIMED EMBODIMENTS

[0005] Embodiments disclosed herein relate to a process for upgrading residuum hydrocarbons. The process may include: feeding pitch, hydrogen, and a partially spent catalyst recovered from a hydrocracking reactor to an ebullated bed pitch hydrocracking reactor; contacting the pitch, hydrogen, and the catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; and separating the distillate hydrocarbons from the catalyst. In one aspect, there is provided a process for upgrading pitch, the process comprising: hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor; recovering a partially spent catalyst from the ebullated bed hydrocracking reactor; grinding the recovered partially spent catalyst; feeding pitch, hydrogen, and ~~a~~ the ground partially spent catalyst ~~recovered from a hydrocracking reactor~~ to an ebullated bed pitch hydrocracking reactor; contacting the pitch, hydrogen, and the partially spent catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the partially spent catalyst. In some embodiments, the process may include selecting the ebullated bed pitch hydrocracking reactor reaction conditions to be at or below the level where sediment formation would otherwise become excessive and prevent continuity of operations.

[0006] Embodiments disclosed herein relate to a process for upgrading residuum hydrocarbons. The process may include: feeding pitch, hydrogen, and a spent or partially spent catalyst recovered from a hydrocracking reactor to a pitch hydrocracking reactor; contacting the pitch, hydrogen, and the catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the catalyst. In another aspect, there is provided a

process for upgrading pitch, the process comprising: feeding pitch, hydrogen, and a spent or partially spent catalyst recovered from a hydrocracking reactor to a pitch hydrocracking reactor; contacting the pitch, hydrogen, and the catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the catalyst; fractionating the distillate hydrocarbons in a vacuum distillation tower to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction; and recycling the vacuum distillation tower bottoms fraction to the pitch hydrocracking reactor.

In another aspect, there is provided a process for upgrading pitch, the process comprising: hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor; recovering a partially spent catalyst from the ebullated bed hydrocracking reactor; recovering an effluent from the hydrocracking reaction system; fractionating the effluent to produce two or more hydrocarbon fractions; solvent deasphalting at least one of the two or more hydrocarbon fractions to produce a deasphalted oil fraction and pitch; feeding the pitch, hydrogen, and the partially spent catalyst to an ebullated bed pitch hydrocracking reactor; contacting the pitch, hydrogen, and the partially spent catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the partially spent catalyst.

In another aspect, there is provided a process for upgrading pitch, the process comprising: feeding pitch, hydrogen, and a partially spent catalyst recovered from a hydrocracking reactor to an ebullated bed pitch hydrocracking reactor; contacting the pitch, hydrogen, and the partially spent catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the partially spent catalyst; fractionating the distillate hydrocarbons in a vacuum distillation tower to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction comprising unreacted pitch;

and recycling the vacuum distillation tower bottoms fraction to the ebullated bed pitch hydrocracking reactor.

In another aspect, there is provided a process for upgrading pitch, the process comprising: hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor; recovering a spent or partially spent catalyst from the ebullated bed hydrocracking reactor; grinding the recovered spent or partially spent catalyst; feeding pitch, hydrogen, and the ground spent or partially spent catalyst to a pitch hydrocracking reactor; contacting the pitch, hydrogen, and the spent or partially spent catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the spent or partially spent catalyst.

In another aspect, there is provided a process for upgrading pitch, the process comprising: hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor; recovering a spent or partially spent catalyst from the ebullated bed hydrocracking reactor; recovering an effluent from the hydrocracking reaction system; fractionating the effluent to produce two or more hydrocarbon fractions; solvent deasphalting at least one of the two or more hydrocarbon fractions to produce a deasphalted oil fraction and pitch; feeding the pitch, hydrogen, and the spent or partially spent catalyst to a pitch hydrocracking reactor; contacting the pitch, hydrogen, and the spent or partially spent catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; separating the distillate hydrocarbons from the spent or partially spent catalyst.

[0007] Embodiments disclosed herein relate to a system for upgrading residuum hydrocarbons. The system may include: a residuum hydrocarbon conversion reactor system for contacting a residuum hydrocarbon, hydrogen, and a hydrocracking catalyst to convert at least a portion of the residuum hydrocarbon to distillate range hydrocarbons; a separation system for fractionating the distillate range hydrocarbons into two or more hydrocarbon fractions including a vacuum tower bottoms fraction;

a separation system for recovering at least some of the spent catalyst from the residuum hydrocarbon conversion reactor system; a solvent deasphalting unit for solvent deasphalting the vacuum tower bottoms fraction to produce a deasphalted oil fraction and a pitch fraction; and a pitch hydrocracking reactor system for contacting the pitch, hydrogen, and spent catalyst recovered from the residuum

hydrocarbon reactor system at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons. In an aspect, there is provided a system for upgrading residuum hydrocarbons, the system comprising: a residuum hydrocarbon conversion reactor system for contacting a residuum hydrocarbon, hydrogen, and a hydrocracking catalyst to convert at least a portion of the residuum hydrocarbon to distillate range hydrocarbons; a separation system for fractionating the distillate range hydrocarbons into two or more hydrocarbon fractions including a vacuum tower bottoms fraction; a separation system for recovering at least some of the spent catalyst from the residuum hydrocarbon conversion reactor system; a grinder for grinding the recovered spent catalyst; a solvent deasphalting unit for solvent deasphalting the vacuum tower bottoms fraction to produce a deasphalted oil fraction and a pitch fraction; a pitch hydrocracking reactor system for contacting the pitch, hydrogen, and the ground spent catalyst at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons. In another aspect, there is provided a system for upgrading pitch, the system comprising: an ebullated bed hydrocracking reactor for hydrocracking a heavy oil feedstock with a catalyst; a separator for recovering the spent catalyst from the ebullated bed hydrocracking reactor; a pitch hydrocracking reactor for contacting pitch, hydrogen, and ~~a~~ the spent catalyst at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons; a separator for separating the distillate hydrocarbons from the spent catalyst; a vacuum distillation tower to fractionate the distillate hydrocarbons to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction; and a recycle system for recycling the vacuum distillation tower bottoms fraction to the pitch hydrocracking reactor. In yet another aspect, there is provided a system for upgrading residuum hydrocarbons, the system comprising: a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor for contacting a heavy oil feedstock, hydrogen, and a hydrocracking catalyst; a separation system for recovering spent catalyst from the ebullated bed hydrocracking reactor; a grinder for grinding the recovered spent catalyst; a pitch hydrocracking reactor system for contacting pitch, hydrogen, and the ground spent catalyst at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

CLAIMS

What is claimed:

1. A process for upgrading pitch, the process comprising:

   hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor;

   recovering a partially spent catalyst from the ebullated bed hydrocracking reactor;

   grinding the recovered partially spent catalyst;

   feeding pitch, hydrogen, and ~~a~~ the ground partially spent catalyst ~~recovered from a hydrocracking reactor~~ to an ebullated bed pitch hydrocracking reactor;

   contacting the pitch, hydrogen, and the partially spent catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

   separating the distillate hydrocarbons from the partially spent catalyst.

2. The process of claim 1, further comprising selecting the ebullated bed pitch hydrocracking reactor reaction conditions to be at or below the level where sediment formation would otherwise become excessive and prevent continuity of operations.

3. The process of claim 1, wherein the catalyst is a partially spent catalyst recovered from an ebullated bed hydrocracking reactor system.

~~4. The process of claim 1, further comprising~~

~~hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor;~~

~~recovering the partially spent catalyst from the ebullated bed hydrocracking reactor.~~

~~5.~~4. The processes of claim 41, wherein the heavy oil feedstock comprises one or more of: virgin atmospheric petroleum residuum; virgin vacuum petroleum residuum; deasphalted oils from a solvent deasphalting unit; tar sands bitumen; atmospheric shale oil-derived residuum; heavy coal-derived liquids; coal gasification byproduct tars; and black oils.

~~6.~~5. The process of claim 41, wherein the ~~spent or~~ partially spent catalyst is recovered from a first hydrocracking reaction stage.

~~7.~~6. The process of claim 41, wherein the ~~spent or~~ partially spent catalyst is recovered from a second hydrocracking reaction stage.

~~8.~~7. The process of claim 41, wherein the ~~spent or~~ partially spent catalyst is a mixture of spent or partially spent catalysts recovered from both a first hydrocracking reaction stage and a second hydrocracking reaction stage.

~~9.~~8. The process of claim 41, further comprising slurrying the recovered partially spent catalyst to form a catalyst slurry fed to the ebullated bed pitch hydrocracking reactor.

~~10. The process of claim 4, further comprising grinding the recovered partially spent catalyst recovered from the ebullated bed hydrocracking reactor.~~

~~11.~~9. The process of claim ~~10~~1, further comprising slurrying the ground catalyst to form a catalyst slurry fed to the ebullated bed pitch hydrocracking reactor.

~~12.~~10. The process of claim 41, further comprising:

recovering an effluent from the hydrocracking reaction system;

fractionating the effluent to produce two or more hydrocarbon fractions;

solvent deasphalting at least one of the two or more hydrocarbon fractions to produce a deasphalted oil fraction and the pitch.

~~13.~~11. The process of claim 1, wherein at least 10% of the pitch is converted to distillate hydrocarbons.

~~14.~~12. The process of claim 1, wherein from about 50% to about 75% of the pitch is converted to distillate hydrocarbons.

~~15.~~13. The process of claim 1, wherein the ebullated bed pitch hydrocracking reactor is operated at a pressure of greater than about 50 bar, a temperature greater than about 350°C, and a liquid hourly space velocity greater than about 0.05 h^{-1}.

~~16.~~14. The process of claim 1, further comprising:

fractionating the distillate hydrocarbons in a vacuum distillation tower to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction comprising unreacted pitch;

recycling the vacuum distillation tower bottoms fraction to the ebullated bed pitch hydrocracking reactor.

~~17.~~15. The process of claim ~~16~~14, further comprising mixing the vacuum tower distillation bottoms fraction with a hydrocarbon diluent comprising at least one of a cycle oil, a slurry oil, and an aromatics-rich solvent.

~~18.~~16. The process of claim ~~16~~14, further comprising:

cooling and solidifying the vacuum distillation tower bottoms fraction;

grinding the solidified vacuum tower distillation bottoms and the spent or partially spent catalyst to form a ground mixture;

slurrying the ground mixture in a liquid hydrocarbon to form a slurry; and

feeding the slurry to the ebullated bed pitch hydrocracking reactor as at least a portion of the pitch and the catalyst fed to the ebullated bed pitch hydrocracking reactor.

~~19.~~17. A process for upgrading pitch, the process comprising:

feeding pitch, hydrogen, and a spent or partially spent catalyst recovered from a hydrocracking reactor to a pitch hydrocracking reactor;

contacting the pitch, hydrogen, and the catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

separating the distillate hydrocarbons from the catalyst;

fractionating the distillate hydrocarbons in a vacuum distillation tower to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction; and

recycling the vacuum distillation tower bottoms fraction to the pitch hydrocracking reactor.

~~20.~~18. The process of claim ~~19~~17, wherein the catalyst is a spent or partially spent catalyst recovered from an ebullated bed hydrocracking reactor.

~~21.~~19. The process of claim ~~19~~17, further comprising

hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor;

recovering the spent or partially spent catalyst from the ebullated bed hydrocracking reactor.

~~22.~~20. The process of claim ~~21~~19, wherein the spent or partially spent catalyst is recovered from a first hydrocracking reaction stage.

~~23.~~21. The process of claim ~~21~~19, wherein the spent or partially spent catalyst is recovered from a second hydrocracking reaction stage.

~~24.~~22. The process of claim ~~21~~19, wherein the spent or partially spent catalyst is a mixture of spent or partially spent catalysts recovered from both a first hydrocracking reaction stage and a second hydrocracking reaction stage.

~~25.~~23. The process of claim ~~21~~19, further comprising slurrying the catalyst to form a catalyst slurry fed to the ebullated bed pitch hydrocracking reactor.

~~26.~~24. The process of claim ~~21~~19, further comprising grinding the spent or partially spent catalyst recovered from the ebullated bed hydrocracking reactor.

~~27.~~25. The process of claim ~~26~~24, further comprising slurrying the ground catalyst to form a catalyst slurry fed to the ebullated bed pitch hydrocracking reactor.

~~28.~~26. The process of claim ~~21~~19, further comprising:

recovering an effluent from the hydrocracking reaction system;

fractionating the effluent to produce two or more hydrocarbon fractions;

solvent deasphalting at least one of the two or more hydrocarbon fractions to produce a deasphalted oil fraction and the pitch.

~~29.~~27. The process of claim ~~19~~17, wherein at least 10% of the pitch is converted to distillate hydrocarbons.

~~30.~~28. The process of claim ~~19~~17, wherein from about 50% to about 75% of the pitch is converted to distillate hydrocarbons.

~~31.~~29. The process of claim ~~19~~17, wherein the ebullated bed pitch hydrocracking reactor is operated at a pressure of greater than about 50 bar, a temperature greater than about 350°C, and a liquid hourly space velocity greater than about 0.05 h^{-1}.

~~32. The process of claim 19, further comprising:~~

~~fractionating the distillate hydrocarbons in a vacuum distillation tower to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction;~~

~~recycling the vacuum distillation tower bottoms fraction to the ebullated bed pitch hydrocracking reactor.~~

~~33.~~30. The process of claim ~~32~~17, further comprising mixing the vacuum tower distillation bottoms fraction with a hydrocarbon diluent comprising at least one of an FCC cycle oil, a slurry oil, and an aromatics-rich solvent.

~~34.~~31. The process of claim ~~32~~17, further comprising:

cooling and solidifying the vacuum distillation tower bottoms fraction;

grinding the solidified vacuum tower distillation bottoms and the spent or partially spent catalyst to form a ground mixture;

slurrying the ground mixture in a liquid hydrocarbon to form a slurry; and

feeding the slurry to the ebullated bed pitch hydrocracking reactor as at least a portion of the pitch and the catalyst fed to the ebullated bed pitch hydrocracking reactor.

~~35.~~32. A system for upgrading residuum hydrocarbons, the system comprising:

a residuum hydrocarbon conversion reactor system for contacting a residuum hydrocarbon, hydrogen, and a hydrocracking catalyst to convert at least a portion of the residuum hydrocarbon to distillate range hydrocarbons;

a separation system for fractionating the distillate range hydrocarbons into two or more hydrocarbon fractions including a vacuum tower bottoms fraction;

a separation system for recovering at least some of the spent catalyst from the residuum hydrocarbon conversion reactor system;

a grinder for grinding the recovered spent catalyst;

a solvent deasphalting unit for solvent deasphalting the vacuum tower bottoms fraction to produce a deasphalted oil fraction and a pitch fraction;

a pitch hydrocracking reactor system for contacting the pitch, hydrogen, and the ground spent catalyst at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons.

~~36.~~33. The system of claim ~~35~~32, further comprising a separation system for separating the distillate hydrocarbons from the ground spent catalyst.

~~37.~~34. The system of claim ~~35~~32, wherein the residuum hydrocarbon conversion reactor system comprises one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor.

~~38.~~35. The system of claim ~~37~~34, wherein the grinder is configured to receive spent catalyst from a first hydrocracking reaction stage.

~~39.~~36. The system of claim ~~37~~34, wherein the grinder is configured to receive spent catalyst from a second hydrocracking reaction stage.

~~40.~~37. The system of claim ~~37~~34, wherein the grinder is configured to receive spent catalyst from both a first and a second hydrocracking reaction stage.

~~41.~~38. The system of claim ~~35~~32, further comprising a mixer for forming a slurry of the ground catalyst for feeding the ground catalyst as a slurry to the pitch hydrocracking reactor.

~~42.~~39. The system of claim ~~41~~38, further comprising a freeze unit for cooling and solidifying the vacuum distillation tower bottoms.

~~43.~~40. The system of claim ~~42~~39, wherein the grinder is configured to grind the spent catalyst and the solidified vacuum distillation tower bottoms to form a ground mixture, and wherein the mixer is configured to slurry the ground mixture in a liquid hydrocarbon.

~~44.~~41. A system for upgrading pitch, the system comprising:

an ebullated bed hydrocracking reactor for hydrocracking a heavy oil feedstock with a catalyst;

a separator for recovering the spent catalyst from the ebullated bed hydrocracking reactor;

a pitch hydrocracking reactor for contacting pitch, hydrogen, and ~~a~~ the spent catalyst at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

a separator for separating the distillate hydrocarbons from the spent catalyst;

a vacuum distillation tower to fractionate the distillate hydrocarbons to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction; and

a recycle system for recycling the vacuum distillation tower bottoms fraction to the pitch hydrocracking reactor.

~~45. The system of claim 44, further comprising an ebullated bed hydrocracking reactor for hydrocracking a heavy oil feedstock with a catalyst.~~

~~46. The system of claim 45, further comprising a separator for recovering the spent catalyst from the ebullated bed hydrocracking reactor.~~

~~47.~~42. The system of claim ~~46~~41, further comprising a grinder for grinding the spent catalyst recovered from the ebullated bed hydrocracking reactor.

~~48.~~43. A system for upgrading residuum hydrocarbons, the system comprising:

a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor for contacting a heavy oil feedstock, hydrogen, and a hydrocracking catalyst;

a separation system for recovering spent catalyst from the ebullated bed hydrocracking reactor;

a grinder for grinding the recovered spent catalyst;

a pitch hydrocracking reactor system for contacting pitch, hydrogen, and the ground spent catalyst at reaction conditions of temperature and pressure

sufficient to convert at least a portion of the pitch to distillate hydrocarbons; and

a separation system for separating the distillate hydrocarbons from the ground spent catalyst.

~~49.~~44. The system of claim ~~48~~43, wherein the pitch hydrocracking reactor system comprises an ebullated bed pitch hydrocracking reactor.

~~50.~~45. The system of claim ~~49~~44, wherein the ebullated bed pitch hydrocracking reactor is configured to receive the ground spent catalyst proximate a top of the ebullated bed pitch hydrocracking reactor and to discharge fully spent catalyst proximate a bottom of the ebullated bed pitch hydrocracking reactor.

~~51.~~46. The system of claim ~~48~~43, further comprising a metals reclamation system for reclaiming metals from the fully spent catalyst.

~~52.~~47. The system of claim ~~49~~44, wherein the ebullated bed pitch hydrocracking reactor is configured to receive a slurry of the ground spent catalyst proximate a bottom of the ebullated bed pitch hydrocracking reactor.

~~53.~~48. The system of claim ~~48~~43, wherein the pitch hydrocracking reactor system is a single pass upflow reactor.

~~54.~~49. The system of claim ~~48~~43, further comprising a quench system for quenching a hydrocarbon effluent from the pitch hydrocracking reactor system.

50. A process for upgrading pitch, the process comprising:

hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor;

recovering a partially spent catalyst from the ebullated bed hydrocracking reactor;

recovering an effluent from the hydrocracking reaction system;

fractionating the effluent to produce two or more hydrocarbon fractions;

solvent deasphalting at least one of the two or more hydrocarbon fractions to produce a deasphalted oil fraction and pitch;

feeding the pitch, hydrogen, and the partially spent catalyst to an ebullated bed pitch hydrocracking reactor;

contacting the pitch, hydrogen, and the partially spent catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

separating the distillate hydrocarbons from the partially spent catalyst.

51. A process for upgrading pitch, the process comprising:

feeding pitch, hydrogen, and a partially spent catalyst recovered from a hydrocracking reactor to an ebullated bed pitch hydrocracking reactor;

contacting the pitch, hydrogen, and the partially spent catalyst in the ebullated bed pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

separating the distillate hydrocarbons from the partially spent catalyst;

fractionating the distillate hydrocarbons in a vacuum distillation tower to produce one or more hydrocarbon fractions and a vacuum distillation tower bottoms fraction comprising unreacted pitch; and

recycling the vacuum distillation tower bottoms fraction to the ebullated bed pitch hydrocracking reactor.

52. A process for upgrading pitch, the process comprising:

hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor;

recovering a spent or partially spent catalyst from the ebullated bed hydrocracking reactor;

grinding the recovered spent or partially spent catalyst;

feeding pitch, hydrogen, and the ground spent or partially spent catalyst to a pitch hydrocracking reactor;

contacting the pitch, hydrogen, and the spent or partially spent catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

separating the distillate hydrocarbons from the spent or partially spent catalyst.

53. A process for upgrading pitch, the process comprising:

hydrocracking a heavy oil feedstock in a hydrocracking reaction system comprising one or more hydrocracking reaction stages comprising an ebullated bed hydrocracking reactor;

recovering a spent or partially spent catalyst from the ebullated bed hydrocracking reactor;

recovering an effluent from the hydrocracking reaction system;

fractionating the effluent to produce two or more hydrocarbon fractions;

solvent deasphalting at least one of the two or more hydrocarbon fractions to produce a deasphalted oil fraction and pitch;

feeding the pitch, hydrogen, and the spent or partially spent catalyst to a pitch hydrocracking reactor;

contacting the pitch, hydrogen, and the spent or partially spent catalyst in the pitch hydrocracking reactor at reaction conditions of temperature and pressure sufficient to convert at least a portion of the pitch to distillate hydrocarbons;

separating the distillate hydrocarbons from the spent or partially spent catalyst.