

to process the SDA pitch directly in a RHU. Nonetheless, economic processes to achieve high hydrocarbon conversions and sulfur removal are desired.

SUMMARY

[0005] In one aspect, there is provided a process for upgrading residuum hydrocarbons. The process includes the following steps: contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr; recovering a first effluent from the first ebullated bed hydroconversion reactor system; contacting the first effluent and hydrogen with a second hydroconversion catalyst in a fixed bed second hydroconversion reactor system; recovering a second effluent from the second hydroconversion reactor system; contacting the second effluent and hydrogen with a third hydroconversion catalyst in a second ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr; recovering a third effluent from the second ebullated bed hydroconversion reactor system; and fractionating the third effluent from the second ebullated bed hydroconversion reactor system to recover one or more hydrocarbon fractions.

[0006] In another aspect, there is provided a system for upgrading residuum hydrocarbons. The system includes the following: a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent; a second hydroconversion reactor system including a fixed bed for contacting the first effluent and hydrogen with a second hydroconversion catalyst to produce a second effluent; a second ebullated bed hydroconversion reactor system for contacting the second effluent and hydrogen with a third hydroconversion catalyst to produce a third effluent and a fractionation unit to fractionate the third effluent to recover one or more hydrocarbon fractions and the vacuum residuum fraction.

[0007] In another aspect, there is provided a process for upgrading residuum hydrocarbons. The process includes the following steps: contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr; recovering a first effluent from the first ebullated bed hydroconversion reactor system; contacting the first effluent and hydrogen with a second hydroconversion catalyst in a second fixed bed hydroconversion reactor system; recovering a second effluent

from the second hydroconversion reactor system; contacting the second effluent and hydrogen with a third hydroconversion catalyst in a third ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr; recovering a third effluent from the third hydroconversion reactor system; combining ~~the a~~ a second portion of the first effluent and the third effluent to form a combined feed; feeding the combined feed to a separator to produce a vapor fraction and a liquid fraction; fractionating the liquid fraction to recover the vacuum residuum fraction in a first fractionation system; contacting the vapor fraction with a fourth hydroconversion catalyst in a fourth hydroconversion reactor system; recovering a fourth effluent from the third hydroconversion reactor system; fractionating the fourth effluent to recover one or more hydrocarbon fractions in a second fractionation system.

[0008] In another aspect, there is provided a system for upgrading residuum hydrocarbons. The system includes the following: a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent; a second fixed bed hydroconversion reactor system for contacting the first effluent and hydrogen with a second hydroconversion catalyst to produce a second effluent; a second ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr for contacting the second effluent and hydrogen with a third hydroconversion catalyst to produce a third effluent; and a separator for separating a combined fraction of the second effluent and the third effluent to recover a liquid fraction and a vapor fraction; a fractionation unit to fractionate the liquid to recover the vacuum residuum fraction; a fourth hydroconversion reactor system for contacting the vapor fraction with a fourth hydroconversion catalyst to produce a fourth effluent; and a fractionation unit to fractionate the fourth effluent to recover one or more hydrocarbon fractions.

In another aspect, there is provided a process for upgrading residuum hydrocarbons, the process comprising: contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first fixed bed hydroconversion reactor system; recovering a first effluent from the first hydroconversion reactor system;

contacting the first effluent and hydrogen with a second hydroconversion catalyst in a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr; recovering a second effluent from the first ebullated bed hydroconversion reactor system; contacting the second effluent and hydrogen with a third hydroconversion catalyst in a second ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr; recovering a third effluent from the second ebullated bed hydroconversion reactor system; and fractionating the third effluent from the second ebullated bed hydroconversion reactor system to recover one or more hydrocarbon fractions.

[0009] Other embodiments and advantages will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0010] Figure 1 is a simplified process flow diagram of a process for upgrading residuum hydrocarbon feedstocks according to embodiments disclosed herein.

[0011] Figure 2 is a simplified process flow diagram of a process for upgrading residuum hydrocarbon feedstocks according to embodiments disclosed herein.

CLAIMS

What is claimed:

1. A process for upgrading residuum hydrocarbons, the process comprising:
 - contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr;
 - recovering a first effluent from the first ebullated bed hydroconversion reactor system;
 - contacting the first effluent and hydrogen with a second hydroconversion catalyst in a fixed bed second hydroconversion reactor system;
 - recovering a second effluent from the second hydroconversion reactor system;
 - contacting the second effluent and hydrogen with a third hydroconversion catalyst in a second ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr;
 - recovering a third effluent from the second ebullated bed hydroconversion reactor system; and
 - fractionating the third effluent from the second ebullated bed hydroconversion reactor system to recover one or more hydrocarbon fractions.
- ~~2. The process of claim 1, wherein the second hydroconversion reactor system comprises a fixed bed reactor.~~
- ~~3.2.~~ The process of claim 1, further comprising recycling a vacuum residuum hydrocarbon fraction obtained from the fractionating to at least one of the first ebullated bed hydroconversion reactor system, the second hydroconversion reactor system, and the second ebullated bed hydroconversion reactor system.
- ~~4.3.~~ The process of claim 1, further comprising recycling a vacuum gas oil hydrocarbon fraction obtained from the fractionating to at least one of the first ebullated bed hydroconversion reactor system, the second hydroconversion reactor system, and the second ebullated bed hydroconversion reactor system.
- ~~5.4.~~ The process of claim 1, wherein the residuum hydrocarbon fraction comprises at least one of petroleum atmospheric or vacuum residua, deasphalted oils, deasphalter pitch, hydrocracked atmospheric tower or vacuum tower bottom, straight run vacuum gas oil, hydrocracked vacuum gas oil, fluid catalytically cracked (FCC) slurry oils,

vacuum gas oil from an ebullated bed process, shale-derived oils, coal-derived oils, bioderived crude oils, tar sands bitumen, tall oils, black oils.

~~6-5.~~ The process of claim 1, wherein the contacting in the first ebullated bed hydroconversion reactor system comprises selecting operating conditions sufficient to result in a hydrocarbon conversion of the residuum hydrocarbon fraction in the range from ~~about~~ 25 wt% to ~~about~~ 35 wt% and metals removal of the residuum hydrocarbon fraction in the range from ~~about~~ 50 wt% to ~~about~~ 80 wt%.

~~7-6.~~ The process of claim 1, wherein the contacting in the second hydroconversion reactor system comprises selecting operating conditions sufficient to result in a hydrocarbon conversion of the first effluent in the range from ~~about~~ 40 wt% to ~~about~~ 55 wt%, a desulfurization/denitrogenation rate of the first effluent in the range from ~~about~~ 70 to ~~about~~ 85%, and Conradson Carbon Residue removal of the first effluent is in the range from ~~about~~ 60 wt% to ~~about~~ 70 wt%.

~~8-7.~~ The process of claim 1, wherein the contacting in the second ebullated bed hydroconversion reactor system comprises selecting operating conditions sufficient to result in a hydrocarbon conversion of the second effluent in the range from ~~about~~ 30 wt% to ~~about~~ 75 wt% and a desulfurization/denitrogenation rate of the second effluent in the range from ~~about~~ 85 to ~~about~~ 95%.

~~9-8.~~ The process of claim 1, wherein a fuel oil produced via the fractionating the second ebullated bed hydroconversion reactor system effluent has a sulfur content of ~~about~~ 1.0 wt% or less.

~~10-9.~~ The process of claim 1, wherein a portion of the first effluent, a portion of the second effluent and the third effluent is fed to a common fractionation system.

~~11-10.~~ The process of claim 1, wherein a portion of the first effluent and a portion of the third effluent is fed to a common fractionation system.

~~12-11.~~ The process of claim 1, wherein an overall conversion of the residuum hydrocarbon fraction is in the range from ~~about~~ 70 wt% to ~~about~~ 80 wt%.

~~13-12.~~ The process of claim 1, wherein the temperature in the second ebullated-bed hydroconversion system is greater than the temperature in the first ebullated-bed hydroconversion system.

~~14-13.~~ The process of claim 1, further comprising separating the first effluent into a liquid product and a vapor product, wherein contacting the first effluent and hydrogen comprises contacting the liquid product and hydrogen with the second hydroconversion catalyst.

~~15.~~14. The process of claim 1, further comprising separating the second effluent into a liquid product and a vapor product, wherein contacting the ~~first~~-second effluent and hydrogen comprises contacting the liquid product and hydrogen with the third hydroconversion catalyst.

~~16.~~15. A system for upgrading residuum hydrocarbons, the system comprising:

- a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent;
- a second hydroconversion reactor system including a fixed bed for contacting the first effluent and hydrogen with a second hydroconversion catalyst to produce a second effluent;
- a second ebullated bed hydroconversion reactor system for contacting the second effluent and hydrogen with a third hydroconversion catalyst to produce a third effluent and
- a fractionation unit to fractionate the third effluent to recover one or more hydrocarbon fractions and the vacuum residuum fraction.

~~17. The system of claim 16, wherein the second hydroconversion reactor system includes a fixed bed hydroconversion reactor system.~~

~~18.~~16. A process for upgrading residuum hydrocarbons, the process comprising:

- contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr;
- recovering a first effluent from the first ebullated bed hydroconversion reactor system;
- contacting the first effluent and hydrogen with a second hydroconversion catalyst in a second fixed bed hydroconversion reactor system;
- recovering a second effluent from the second hydroconversion reactor system;
- contacting the second effluent and hydrogen with a third hydroconversion catalyst in a third ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr;
- recovering a third effluent from the third hydroconversion reactor system;
- combining ~~the a~~ a second portion of the first effluent and the third effluent to form a combined feed;

feeding the combined feed to a separator to produce a vapor fraction and a liquid fraction;
fractionating the liquid fraction to recover the vacuum residuum fraction in a first fractionation system;
contacting the vapor fraction with a fourth hydroconversion catalyst in a fourth hydroconversion reactor system;
recovering a fourth effluent from the third hydroconversion reactor system;
fractionating the fourth effluent to recover one or more hydrocarbon fractions in a second fractionation system.

- 49.17. A system for upgrading residuum hydrocarbons, the system comprising:
- a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent;
 - a second fixed bed hydroconversion reactor system for contacting the first effluent and hydrogen with a second hydroconversion catalyst to produce a second effluent;
 - a second ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr for contacting the second effluent and hydrogen with a third hydroconversion catalyst to produce a third effluent; and
 - a separator for separating a combined fraction of the second effluent and the third effluent to recover a liquid fraction and a vapor fraction;
 - a fractionation unit to fractionate the liquid to recover the vacuum residuum fraction;
 - a fourth hydroconversion reactor system for contacting the vapor fraction with a fourth hydroconversion catalyst to produce a fourth effluent; and
 - a fractionation unit to fractionate the fourth effluent to recover one or more hydrocarbon fractions.

~~20-18.~~ A process for upgrading residuum hydrocarbons, the process comprising:

- contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first fixed bed hydroconversion reactor system;
- recovering a first effluent from the first hydroconversion reactor system;
- contacting the first effluent and hydrogen with a second hydroconversion catalyst in a first ebullated bed hydroconversion reactor system operating in a range from 105,000 °F-Bara-Hr to 446,000 °F-Bara-Hr;
- recovering a second effluent from the first ebullated bed hydroconversion reactor system;
- contacting the second effluent and hydrogen with a third hydroconversion catalyst in a second ebullated bed hydroconversion reactor system operating in a range from 215,000°F-Bara-Hr to 755,000°F-Bara-Hr;
- recovering a third effluent from the second ebullated bed hydroconversion reactor system; and
- fractionating the third effluent from the second ebullated bed hydroconversion reactor system to recover one or more hydrocarbon fractions.