

-1-

PROCESS FOR PRODUCING HIGH QUALITY COKE IN DELAYED COKER UTILIZING MIXED SOLVENT DEASPHALTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 62/327,661 filed April 26, 2016, incorporated herein by reference.

TECHNICAL FIELD

[0002] Embodiments of the present disclosure generally relates to processes for producing high quality coke, and more specifically relates to processes for producing high quality coke using mixed solvent deasphalting.

BACKGROUND

[0003] Coke, specifically, high quality coke is utilized in various industrial applications. For example, high quality coke such as anode grade coke may be used in the aluminum industry and needle grade coke may be used in the steel industry. Coking units are conventional oil refinery processing units that convert low value residual oil, from the vacuum distillation column or the atmospheric distillation column into low molecular weight hydrocarbon gases, naphtha, light and heavy gas oils, and petroleum coke. The most commonly used coking unit is a delayed coker. In a basic delayed coking process, fresh feedstock is introduced into the lower part of a fractionator. The fractionator bottoms, which include heavy recycle material and fresh feedstock, are passed to a furnace and heated to a coking temperature. The hot feed then goes to a coke drum maintained at coking conditions where the feed is cracked to form light products while heavy free radical molecules form heavier polynuclear aromatic compounds, which are referred to as “coke.” With a short residence time in the furnace, coking of the feed is thereby “delayed” until it is discharged into a coking drum. The volatile components are recovered as coker vapor and returned to the fractionator, and coke is deposited on the interior of the drum. When the coke drum is full of coke, the feed is switched to another drum and the full drum is cooled and emptied by conventional methods, such as by hydraulic means or by mechanical means.

-2-

[0004] That being said, residual oil is known to have a significant amount of asphalt and other impurities which decreases the yield of high quality coke. Thus, conventional approaches use upstream high severity hydrotreating and hydrocracking to purify the residual oil, such that the purified residual oil may be converted into high quality coke precursor, also called green coke, in the delayed coker. For example, high severity hydrotreating process may operate at hydrogen partial pressures greater than 150 bars. The green coke produced in the delayed coker may then be calcined to produce anode coke or needle coke. While the hydrotreating upstream of the delayed coker yields green coke, it is very expensive due to its high pressure requirement.

SUMMARY

[0005] Accordingly, ongoing needs exist for improved methods and systems for producing high quality coke.

[0006] Embodiments of the present disclosure are directed to producing high quality coke using a mixed solvent deasphalting upstream of a delayed coker. In addition to producing high quality coke, replacing the high severity hydrotreating and hydrocracking processes with mixed solvent deasphalting, or with mixed solvent deasphalting and low severity hydrotreating significantly reduces the costs for producing high quality coke.

[0007] In one embodiment, a process for producing green coke from residual oil is provided. The process comprises introducing residual oil and a solvent mixture into a mixing vessel to produce a feed mixture, the solvent mixture comprising at least one paraffinic solvent with a carbon number from 3 to 8 and at least one aromatic solvent, where the solvent mixture comprises from 0.1 to 10 % by volume of aromatic solvent and 90 to 99.9% by volume of paraffinic solvent, passing the feed mixture to a solvent deasphalting unit to produce a deasphalted oil (DAO) fraction and an asphalt fraction, and passing the DAO fraction to a delayed coker to produce the green coke and a delayed coker effluent.

[0008] In another process for producing green coke from residual oil, the process comprises introducing residual oil and a solvent mixture into a mixing vessel to produce a

feed mixture, the solvent mixture comprising at least one paraffinic solvent with a carbon number from 3 to 8 and at least one aromatic solvent, passing the feed mixture to a solvent deasphalting unit to produce a deasphalted oil (DAO) fraction and an asphalt fraction, passing the DAO fraction to a hydrotreater unit to produce a hydrotreated DAO fraction, and passing the hydrotreated DAO fraction to a delayed coker to produce the high quality coke and a delayed coker effluent.

[0009] Additional features and advantages of the described embodiments will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the described embodiments, including the detailed description which follows, the claims, as well as the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic depiction of a solvent deasphalting unit with mixed solvent feed upstream of a delayed coker in accordance with one or more embodiments of the present disclosure.

[0011] FIG. 2 is a schematic depiction of a solvent deasphalting unit with mixed solvent feed upstream of a hydrotreater and delayed coker in accordance with one or more embodiments of the present disclosure.

[0012] FIG. 3 is another schematic depiction of solvent deasphalting unit with mixed solvent feed upstream of a hydrotreater and delayed coker in accordance with one or more embodiments of the present disclosure.

[0013] FIG. 4 is another schematic depiction of solvent deasphalting unit with mixed solvent feed upstream of a separator, a hydrotreater, and delayed coker in accordance with one or more embodiments of the present disclosure.

-4-

[0014] The embodiments set forth in the drawings are illustrative in nature and not intended to be limiting to the claims. Moreover, individual features of the drawings will be more fully apparent and understood in view of the detailed description.

DETAILED DESCRIPTION

[0015] Embodiments of the present disclosure are directed to a process for producing high quality coke from residual oil.

[0016] As used in the application, "residual oil" refers to the product of vacuum distillation or atmospheric distillation obtained in oil refineries. Atmospheric residue is defined as hydrocarbons boiling at a temperature of at least 350 °C and vacuum residue is defined as hydrocarbons boiling at a temperature of at least 450 °C.

[0017] As used in the application, "anode coke", "fuel coke", and "needle coke" are defined by the ranges and properties provided in the following Table 1. Fuel grade coke, which generally has greater than 3.5 weight (wt) % of sulfur, and anode coke, which generally has less than 3.5 weight wt% sulfur, are often distinguished based on the sulfur content in the respective cokes.

[0018] Table 1

Property	Units	Fuel Coke	Calcined High quality Coke (Anode Coke)	Calcined Needle Coke
Bulk Density	Kilograms per cubic meter (Kg/m ³)	880	720-800	670-720
Sulfur	wt%	3.5-7.5	1.0-3.5	0.2-0.5
Nitrogen	Parts per million by weight (Ppmw)	6,000	---	50
Nickel	Ppmw	500	200	7 max
Vanadium	Ppmw	150	350	---
Volatile Combustible Material	wt%	12	0.5	0.5
Ash Content	wt%	0.35	0.40	0.1
Moisture Content		8-12	0.3	0.1
Hardgrove Grindability Index (HGI)	wt%	35-70	60-100	---

Coefficient of thermal expansion, E+7	°C	---	---	1-5
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[0019] Referring to the embodiments depicted in FIGS. 1-4, residual oil **101** and a solvent mixture is added to a mixing vessel **110** to produce a feed mixture **112**. The solvent mixture comprises at least one paraffinic solvent **102** with a carbon number from 3 to 8 and at least one aromatic solvent **103**. As shown in FIGS. 1-4, the paraffinic solvent **102** and aromatic solvent **103** are delivered as separate feeds to the mixing vessel **110**; however, it is contemplated that the paraffinic solvent **102** and aromatic solvent **103** could be mixed prior to passing to the mixing vessel **110**. In one embodiment, the solvent mixture comprises from 0.1 to 10 % by volume of aromatic solvent and 90 to 99.9 % by volume of paraffinic solvent. In another embodiment, the solvent mixture comprises from 3 to 5 % by volume of aromatic solvent and 95 to 97 % by volume of paraffinic solvent.

[0020] Paraffinic solvents precipitate and separate asphalt from oil solutions to produce demetallized or deasphalted oil. Deasphalted oil yield increases with increasing carbon number of the solvent; however, the quality of the deasphalted oil may decrease. Aromatics dissolve more oil and asphalts and as a result more oil may be recovered in the solvent deasphalting step at a cost of deasphalted oil quality. Without being bound by theory, it was found that changing the percentage of the aromatic solvent may impact the quality of the coke that is produced in the coking process in the delayed coker. By using up to 10 % by volume of aromatic solvent, from 0.1 to 5% by volume of aromatic solvent, or from 3 to 5% by volume of aromatic solvent, the present embodiments increase deasphalted oil yield while maintaining the quality of the deasphalted oil at sufficient levels for the production of high quality coke.

[0021] Referring again to FIGS. 1-4, the feed mixture **112** is passed to a solvent deasphalting unit **120** to produce a deasphalted oil (DAO) fraction **122** and an asphalt fraction **124**. As shown in FIG. 1, the DAO fraction **122** may be passed to a delayed coker **140** to produce green coke **144** and a delayed coker effluent **142**

[0022] Various aromatic and paraffinic solvents are contemplated for use in the solvent mixture. Solvents can be selected based on their Hildebrand solubility parameters or on the basis of two-dimensional solubility factors. The overall Hildebrand solubility parameter is a well-known measure of polarity and has been tabulated for numerous compounds. (*See, for example*, Journal of Paint Technology, Vol. 39, No. 505, February 1967). The solvents can also be described by two-dimensional solubility parameters, i.e., the complexing solubility parameter and the field force solubility parameter. (*See, for example*, I. A. Wiehe, Ind. & Eng. Res., 34(1995), 661). The complexing solubility parameter component, which describes the hydrogen bonding and electron donor-acceptor interactions, measures the interaction energy that requires a specific orientation between an atom of one molecule and a second atom of a different molecule. The field force solubility parameter, which describes van der Waal's and dipole interactions, measures the interaction energy of the liquid that is not affected by changes in the orientation of the molecules.

[0023] As defined in the application, a polar solvent is a solvent having an overall Hildebrand solubility parameter greater than about 8.5 or a complexing solubility parameter of greater than one and a field force parameter value greater than 8. Examples of polar solvents suitable in the present solvent mixture include aromatic solvents, such as single ring aromatic compounds including toluene (8.91), benzene (9.15), and xylene (8.85). Thus, the solvent mixture may comprise a mixture of polar aromatic solvents and nonpolar paraffinic solvents. In one or more embodiments, the paraffinic solvent may comprise C₃-C₁₂ paraffins, which are solvents having a carbon number from 3 to 12. In further embodiments, the paraffinic solvent may comprises C₃-C₈ paraffins. Optionally, the solvent mixture comprises at least one olefinic solvent. Like the paraffinic solvent, the olefinic solvent may also have a carbon number in the range of 3 to 8.

[0024] Referring again to FIGS. 1-4, various processing parameters are considered suitable for the operation of the solvent deasphalting unit **120**. The solvent deasphalting unit **120** operates at a temperature and pressure less than the supercritical temperature and pressure, respectively, of the solvent mixture. In one or more embodiments, the solvent deasphalting unit may operate at a temperature from 50 to 400 °C, or from 60 to 300 °C,

-7-

or from 60 to 200 °C, or at approximately 70 °C. Similarly, in one or more embodiments, the solvent deasphalting unit **120** may operate at a pressure from 20 to 80 bars, or from 30 to 60 bars, or at 40 bars. Additionally, the yield of deasphalted oil fraction and asphalt fraction may be adjusted by varying the ratio of the paraffinic solvent to the residual oil. In one or more embodiments, the ratio by weight of the paraffinic solvent to the residual oil is from 0.1 to 20, or from 5 to 10, or from 6 to 8. Moreover, the ratio of the solvent mixture (paraffinic plus aromatic solvents) to residual oil is from 0.1:1 to 10:1 by volume, or from 2:1 to 10:1 by volume.

[0025] While the present application is not limited to specific reactor systems for the solvent deasphalting unit, FIG. 3 depicts one possible example of a solvent deasphalting unit **120** comprising a primary settler tank **120a** and a secondary settler tank **120b**. Primary settler tank **120a** includes an inlet for receiving feed mixture **112** and an outlet for discharging an intermediate DAO fraction **115** and several outlets for discharging a first asphalt fraction **124a**, including a solid adsorbent, if used. Secondary settler tank **120b** may receive the intermediate DAO fraction **115** optionally at multiple ends as shown, and may output the DAO stream **122** and a second asphalt fraction **124b**. The first asphalt fraction **124a** and the second asphalt fraction **124b** may undergo further asphalt utilization and conversion steps as depicted by item **160**. For example and not by way of limitation, the asphalt utilization and conversion steps include gasification, delivery to an asphalt pool, pyrolysis, or combinations thereof.

[0026] Referring to the embodiment of FIG. 4, at least one separator and stripper unit **150** may be included downstream of the solvent deasphalting unit **120**. As shown, the separator and stripper unit **150** may remove solvent **151** from the DAO fraction **122** and recycle the solvent **151** back to the solvent deasphalting unit **120**. The DAO fraction after solvent separation **152** may be fed to the delayed coker **140** for the production of green coke.

[0027] As shown in FIGS. 1-4, the delayed coker **140** may include at least two parallel drums **140a**, **140b**, which are operated in a swing mode. When one coke drum is full of coke, the feed is switched to a fresh empty drum, and the full drum is cooled. As shown,

inlet valves **146** and outlet valves **148** may control flow in and out of the delayed coker **140**. The coke remaining in the drums is typically cooled with water and then removed from the coke drum by conventional methods, for example, using hydraulic or mechanical techniques, or both, to dislodge the solid coke from the drum walls for recovery. The green coke **144** in drums **140a**, **140b** may be calcined to produce high quality coke. Various operating parameters are considered suitable for the delayed coker **140**. For example, the temperature may range from 440 to 530 °C, and the pressure may range from 1 to 5 bars.

[0028] In addition to producing green coke **144**, the delayed coker drums **140a**, **140b** also discharges delayed coker effluent **142**, for example, distillates and gases, which are produced during the delayed coking process. Referring to FIGS. 1-4, the fractionator **170** comprises an inlet in fluid communication with the delayed coker effluent **142**. The fractionator **170** also has a series of outlet ports for separating and discharging heavy naphtha **172**, light coker gas oil **173**, and heavy coker gas oil **174**. Fractionator **170** also has an outlet for discharging solvent and light naphtha **175** that is optionally recycled back to the mixing vessel **110**, to the hydrotreater unit **130**, or both. The light naphtha stream comprises a mixture of alkanes and alkenes, whereas the solvent to be recycled includes the paraffinic and aromatic solvents fed to the solvent deasphalting unit **120**. Without being limited by operating parameters, the solvent and light naphtha **175** may have a final boiling point of up to 100 °C. In one embodiment, the fractionator **170** may also discharge unconverted bottoms oil **171** through a bottom port. In another embodiment, at least a portion of this unconverted bottoms oil **171** is recycled to the delayed coker **140** through recycle stream **171a**. In yet another embodiment, at least a portion of this unconverted bottoms oil **171** is recycled to the mixing vessel **110** through recycle stream **171b**. In a further embodiment, at least a portion of this unconverted bottoms oil **171** is recycled to the hydrotreater unit **130** through recycle stream **171c**. While not shown, light gases may be separated from the distillates in a flash unit downstream of the delayed coker **140** but upstream of the fractionator **170**.

[0029] Referring to FIGS. 2-4, the DAO fraction **122** may be passed to a hydrotreater unit **130** to remove sulfur, metals, and nitrogen from the DAO fraction **122** and thereby

produce a hydrotreated DAO fraction **131** upstream of the delayed coker **140**. The hydrotreated DAO fraction **131** may then be passed to a delayed coker **140** to produce green coke **144** and the delayed coker effluent **142**.

[0030] Various hydrotreating processes and components are considered suitable, with extensive variation in the parameters being possible. That being said, when these hydrotreating units (also called hydrocracking units) are operated under high severity conditions, the cost of operating these units may be costly. Without being limited by theory, the present mixed solvent deasphalting may enable the hydrotreater unit **130** to run at lesser severity conditions, which consequently are less costly, while still achieving green coke in the delayed coker **140**. In one or more embodiments, the temperature may be from 300 to 450 °C, or from 340 to 400 °C, whereas the hydrogen partial pressure may vary from 20-150 bar, or from 60 to 100 bar. These pressures are consistent with low severity hydrotreating, and contrast high severity hydrotreating which includes hydrogen partial pressures greater than 150 bars. The LHSV may be from 0.5 to 10 h⁻¹, or from 1 to 2 h⁻¹, and the ratio of hydrogen/DAO fraction may be from 100 to 5000 standard liters per liter, or 100 to 1500 standard liters per liter. Moreover, the parameters may be varied based on the type of high grade coke desired. For example, if needle coke is the desired product, the hydrotreater unit **130** may need to run at higher temperatures or pressures, because needle coke has higher purity requirements than anode coke.

[0031] For example and not by way of limitation, the hydrotreater unit **130** may include fixed bed reactors, ebullated-bed reactors, moving bed reactors, slurry bed reactors or combinations thereof. In a fixed bed reactor, catalyst particles are stationary and do not move with respect to a fixed reference frame. Due to exothermic nature of the reactions, a fixed-bed reactor may have multiple catalysts bed and the effluents are quenched between the beds. Multiple fixed-bed reactors connected in series can be used to achieve a relatively high conversion of heavy feedstocks boiling at a cut point in the range of 300 to 500 °C. An ebullated-bed reactor includes concurrently flowing streams of liquids or slurries of liquids, solids and gas, through a vertically oriented cylindrical vessel containing catalyst. The catalyst is placed in motion in the liquid and has a gross volume dispersed through the liquid medium that is greater than the volume of the mass when

stationary. In an ebullated-bed reactor, the catalyst is in an expanded bed, thereby countering plugging potential problems associated with fixed-bed reactors. The fluidized nature of the catalyst in an ebullated-bed reactor also allows for on-line catalyst replacement of a small portion of the bed. This results in a high net bed activity which does not vary with time. In addition, the ebullated-bed reactors are operated in isothermal mode of operation because of back-mixed characteristics of the system. The feed temperature is adjusted to quench the heat generated in the ebullated-bed reactor. Moving-bed reactors combine certain advantages of fixed-bed operations and the relatively easy catalyst replacement of ebullated-bed technology

[0032] Catalysts employed in the hydrotreater unit **130** may include components capable of facilitating the desired removal and conversion of contaminants in the DAO fraction. These catalysts may include supported active metal catalysts, where the active metals may include cobalt, nickel, tungsten, molybdenum or combinations thereof. The support material may be selected from the group consisting of alumina, silica-alumina, titania, titania-silicalite, silica, and zeolites or combination thereof.

[0033] While not shown, various additional treatment units may be included in the previously described embodiments. For example, one or more adsorption columns (not shown) may be disposed upstream of the delayed coker to desulfurize and demetallize the DAO fraction. The adsorption columns may include various adsorbent materials. These materials may be in packaged or slurry form and may include, but are not limited to, attapulgus clay, zeolites, alumina, silica gel, silica-titania, silica-alumina, spent or regenerated catalysts from other refinery operations, as well as activated carbon. In further embodiments, the adsorption columns may include one or more packed bed reactors.

[0034] EXAMPLES

[0035] The following examples illustrate two different embodiments. Referring to FIG. 1 for illustration, Example 1 is a mixed solvent deasphalting system which produces green coke in the delayed coker **140** without a hydrotreater **130** between the solvent deasphalting unit **120** and the delayed coker **140**. In contrast, the system of Example 2 illustrated in

FIG. 3 utilizes a hydrotreater **130** between the solvent deasphalting unit **120** and the delayed coker **140** to produce green coke.

[0036] *Example 1*

[0037] Table 2- Operating Conditions for Example 1

Operating Conditions	Solvent Deasphalting Unit (120)	Delayed Coker (140)
Temperature (°C)	70	490
Pressure (Bars)	40	3
Solvents	Heptane and Toluene	NA
Paraffinic Solvent /Oil Ratio	7	NA

[0038] Table 3- Material Balance for Example 1

Stream#	101	102	103	122	124	142	144
Stream Name	Residual Oil	Heptane	Toluene	DAO	Asphalt	Distillates + Gas	Green Coke
Feed / Product Rate (Kg)	1000.0	7000	210.0	950	50	---	104.9
Density (Kg/L)	0.939	0.684	0.933	---	1.019	1.181	---
API Gr. (°)	19.19	---	20.2	---	7.4	---	---
Sulfur (wt%)	2.281	---	---	2.24	3.15	---	3.35
Nitrogen (Ppmw)	0	---	---	---	---	---	---
MCR (wt%)	6.9	---	---	6.1	22.6	---	---
Nickel (Ppmw)	4	---	---	0	80	---	37

-12-

Stream#	101	102	103	122	124	142	144
Vanadium (Ppmw)	7	---	---	5	40	---	51

[0039] *Example 2*

[0040] Table 4- Operating Conditions for Example 2

Operating Conditions	Solvent deasphalting Unit (120)	Hydrotreater (130)	Delayed Coker (140)
Temperature (°C)	200	380	490
Pressure (Bars)	30	117	3
LHSV (h ⁻¹)	NA	0.435	NA
H ₂ /Oil Ratio	NA	1250	NA
Solvents	Heptane and Toluene	NA	NA
Paraffinic Solvent / Oil Ratio	7	NA	NA

[0041] Table 5- Material Balance for Example 2

Stream#	101	102	103	122	124	142	136	131	144
Stream Name	Residual Oil	Heptane	Toluene	DAO	Asphalt	Distillates + Gas	H ₂	Hydrotreated DAO	Anode Grade Coke
Feed / Product Rate (Kg)	1000.0	7000	540.0	950	48	731	15.2	771.6	105.0
Density (Kg/L)	0.982	0.684	0.924	---	1.003	1.141	---	---	---
API Gr. (°)	12.59	---	21.6	---	5.3	---	---	---	---
Sulfur (wt%)	4.05	---	---	4.0	5.6	---	---	2.0	3.0
Nitrogen (Ppmw)	2900	---	---	---	---	---	---	---	---
MCR (wt%)	16.4	---	---	13.1	78.7	---	---	3.3	---
Nickel (Ppmw)	19	---	---	14.3	109.3	---	---	1.0	49.8
Vanadium (Ppmw)	61	---	---	45.8	350.8	---	---	1.0	76

[0042] It should now be understood that the various aspects of the processes for producing green coke from residual oil are described and such aspects may be utilized in conjunction with various other aspects.

[0043] In a first aspect, the disclosure provides a process for producing green coke from residual oil. The process comprises introducing residual oil and a solvent mixture into a mixing vessel to produce a feed mixture. The solvent mixture comprises at least one paraffinic solvent with a carbon number from 3 to 8 and at least one aromatic solvent. Further, the solvent mixture comprises from 0.1 to 10 % by volume of aromatic solvent

and 90 to 99.9% by volume of paraffinic solvent. The process also comprises passing the feed mixture to a solvent deasphalting unit to produce a deasphalted oil (DAO) fraction and an asphalt fraction and passing the DAO fraction to a delayed coker to produce the green coke and a delayed coker effluent.

[0044] In a second aspect, the disclosure provides a process for producing green coke from residual oil. The process comprises introducing residual oil and a solvent mixture into a mixing vessel to produce a feed mixture. The solvent mixture comprises at least one paraffinic solvent with a carbon number from 3 to 8 and at least one aromatic solvent. The process also comprises passing the feed mixture to a solvent deasphalting unit to produce a deasphalted oil (DAO) fraction and an asphalt fraction, passing the DAO fraction to a hydrotreater unit to produce a hydrotreated DAO fraction, and passing the hydrotreated DAO fraction to a delayed coker to produce the high quality coke and a delayed coker effluent.

[0045] In a third aspect, the disclosure provides the process of the first or second aspects, in which the process further comprises passing the delayed coker effluent to a fractionator unit. The fractionator unit separates the delayed coker effluent into separate fractionator output streams comprising: solvent and light naphtha, heavy naphtha, light coker gas oil, heavy coker gas oil, and unconverted bottoms oil.

[0046] In a fourth aspect, the disclosure provides the process of the third aspect, in which the light naphtha comprises a mixture of alkanes and alkenes.

[0047] In a fifth aspect, the disclosure provides the process of the third or fourth aspects, in which the process further comprises recycling the solvent and light naphtha back to the mixing vessel.

[0048] In a sixth aspect, the disclosure provides the process of any of the third through fifth aspects, in which the solvent has a final boiling point of up to 100 °C.

[0049] In a seventh aspect, the disclosure provides the process of any of the third through sixth aspects, in which the process further comprises recycling the unconverted bottoms oil back to the mixing vessel.

[0050] In an eighth aspect, the disclosure provides the process of the second aspect, in which the process further comprises recycling the unconverted bottoms oil back to the hydrotreater unit.

[0051] In a ninth aspect, the disclosure provides the process of any of the third through eighth aspects, in which the process further comprises recycling the unconverted bottoms oil back to the delayed coker.

[0052] In a tenth aspect, the disclosure provides the process of any of the first through ninth aspects, in which the process further comprises subjecting the asphalt fraction to asphalt utilization and conversion steps.

[0053] In an eleventh aspect, the disclosure provides the process of the tenth aspect, in which the asphalt utilization and conversion steps include gasification, delivery to an asphalt pool, pyrolysis or combinations thereof.

[0054] In a twelfth aspect, the disclosure provides the process of any of the first through eleventh aspects, in which the process further comprises a separator and stripper downstream of the solvent deasphalting unit.

[0055] In a thirteenth aspect, the disclosure provides the process of any of the first through twelfth aspects, in which the solvent deasphalting unit comprises a first settler tank and a second settler tank downstream of the first settler tank.

[0056] In a fourteenth aspect, the disclosure provides the process of the thirteenth aspect, in which the first settler tank converts the feed mixture into an intermediate DAO fraction and a first asphalt fraction.

[0057] In a fifteenth aspect, the disclosure provides the process of the thirteenth or fourteenth aspects, in which the second settler tank converts the intermediate DAO fraction to a second asphalt fraction and the DAO fraction.

[0058] In a sixteenth aspect, the disclosure provides the process of any of the first through fifteenth aspects, in which the delayed coker comprises dual delayed coking drums.

[0059] In a seventeenth aspect, the disclosure provides the process of any of the first through sixteenth aspects, in which the aromatic solvents comprise a single ring aromatic compound.

[0060] In an eighteenth aspect, the disclosure provides the process of any of the first through seventeenth aspects, in which the aromatic solvents comprise benzene, toluene, or combinations thereof.

[0061] In a nineteenth aspect, the disclosure provides the process of any of the first through eighteenth aspects, in which the solvent mixture comprises at least one olefinic solvent.

[0062] In a twentieth aspect, the disclosure provides the process of any of the first through nineteenth aspects, in which the ratio of solvent mixture-to-residual oil in the feed mixture is from 0.1:1 to 10:1 by volume.

[0063] In a twenty-first aspect, the disclosure provides the process of the twentieth aspect, in which the ratio of solvent mixture-to-residual oil is from 2:1 to 10:1 by volume.

[0064] In a twenty-second aspect, the disclosure provides the process of any of the first through twenty-first aspects, in which the process further comprises calcining the green coke from the delayed coker to produce high quality coke.

[0065] In a twenty-third aspect, the disclosure provides the process of the twenty-second aspect, in which the high quality coke comprises anode coke, needle coke, or both.

[0066] In a twenty-fourth aspect, the disclosure provides the process of any of the first through twenty-third aspects, in which the solvent deasphalting unit operates at a temperature and pressure less than the supercritical temperature and pressure of the solvent mixture.

[0067] In a twenty-fifth aspect, the disclosure provides the process of any of the first through twenty-fourth aspects, in which the delayed coker operates at a temperature from 440 °C to 530 °C and a pressure from 1 to 5 Bars.

[0068] In a twenty-sixth aspect, the disclosure provides the process of any of the second through twenty-fifth aspects, in which the hydrotreater operates at a temperature of 300 to 450 °C and a hydrogen partial pressure of 20 to 150 bars.

[0069] In a twenty-seventh aspect, the disclosure provides the process of any of the first through twenty-sixth aspects, in which the aromatic solvents are polar solvents having a Hildebrand solubility parameter of at least 8.5.

[0070] It should be apparent to those skilled in the art that various modifications and variations can be made to the described embodiments without departing from the spirit and scope of the claimed subject matter. Thus it is intended that the specification cover the modifications and variations of the various described embodiments provided such modification and variations come within the scope of the appended claims and their equivalents.

[0071] Throughout this disclosure ranges are provided. It is envisioned that each discrete value encompassed by the ranges are also included. Additionally, the ranges which may be formed by each discrete value encompassed by the explicitly disclosed ranges are equally envisioned.

CLAIMS

1. A process for producing green coke from residual oil comprising:
introducing residual oil and a solvent mixture into a mixing vessel to produce a
5 feed mixture, the solvent mixture comprising at least one paraffinic solvent with a
carbon number from 3 to 8 and at least one aromatic solvent, where the solvent mixture
comprises from 0.1 to 10% by volume of aromatic solvent and 90 to 99.9% by volume
of paraffinic solvent;
passing the feed mixture to a solvent deasphalting unit to produce a deasphalted
10 oil (DAO) fraction and an asphalt fraction; and
passing the DAO fraction to a delayed coker to produce the green coke and a
delayed coker effluent.
2. The process of claim 1, further comprising passing the delayed coker effluent to
15 a fractionator unit, where the fractionator unit separates the delayed coker effluent into
separate fractionator output streams comprising: solvent and light naphtha; heavy
naphtha; light coker gas oil; heavy coker gas oil; and unconverted bottoms oil.
3. The process of claim 2, further comprising recycling the solvent and light
20 naphtha back to the mixing vessel.
4. The process of claim 2, where the solvent has a final boiling point of up to
100°C.
- 25 5. The process of claim 2, further comprising recycling the unconverted bottoms
oil back to one or more of the mixing vessel and the delayed coker.
6. The process of claim 1, further comprising subjecting the asphalt fraction to
asphalt utilization and conversion steps.
- 30 7. The process of claim 6, where the asphalt utilization and conversion steps
include gasification, delivery to an asphalt pool, pyrolysis or combinations thereof.

8. The process of claim 1, further comprising a separator and stripper downstream of the solvent deasphalting unit.
- 5 9. The process of claim 1, where the solvent deasphalting unit comprises a first settler tank and a second settler tank downstream of the first settler tank.
10. The process of claim 9, where the first settler tank converts the feed mixture into an intermediate DAO fraction and a first asphalt fraction.
- 10 11. The process of claim 9, where the second settler tank converts the intermediate DAO fraction to a second asphalt fraction and the DAO fraction.
12. The process of claim 1, where the delayed coker comprises dual delayed coking
15 drums.
13. The process of claim 1, where the aromatic solvents comprise a single ring aromatic compound.
- 20 14. The process of claim 1, where the solvent mixture comprises at least one olefinic solvent.
15. The process of claim 1, where the ratio of solvent mixture-to-residual oil in the feed mixture is from 0.1:1 to 10:1 by volume.
- 25 16. The process of claim 15, where the ratio of solvent mixture-to-residual oil is from 2:1 to 10:1 by volume.
17. The process of claim 1, further comprising calcining the green coke from the
30 delayed coker to produce high quality coke.

18. The process of claim 1, where the solvent deasphalting unit operates at a temperature and pressure less than the supercritical temperature and pressure of the solvent mixture.
- 5 19. The process of claim 1, where the aromatic solvents are polar solvents having a Hildebrand solubility parameter of at least 8.5.
20. A process for producing green coke from residual oil comprising:
- introducing residual oil and a solvent mixture into a mixing vessel to produce a
- 10 feed mixture, the solvent mixture comprising at least one paraffinic solvent with a carbon number from 3 to 8 and at least one aromatic solvent;
- passing the feed mixture to a solvent deasphalting unit to produce a deasphalted oil (DAO) fraction and an asphalt fraction;
- passing the DAO fraction to a hydrotreater unit to produce a hydrotreated DAO
- 15 fraction; and
- passing the hydrotreated DAO fraction to a delayed coker to produce the high quality coke and a delayed coker effluent.