

PRODUCTION OF BTX AROMATICS AND LIGHT GAS OLEFINS FROM CRUDE OIL AND PLASTIC PYROLYSIS OIL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority of U.S. Provisional Patent
5 Application No. 63/131,270, filed December 28, 2020, which is hereby incorporated by reference in its entirety.

FIELD OF INVENTION

[0002] The invention generally relates to a process for producing C₆ to C₈ aromatics and optionally light gas olefins. In one aspect, the invention relates to a process for producing
10 C₆ to C₈ aromatics and light gas olefins from crude oil and/or pyrolysis oil using hydroprocessing.

BACKGROUND OF THE INVENTION

[0003] C₆ to C₈ aromatics such as benzene, toluene, and xylene are important commodity chemicals with continuously increasing demand. For example, benzene, toluene,
15 and/or xylene are used to make various polymers (e.g., polycarbonates, polyesters, nylons, and polyurethanes etc.) having multiple industrial uses. Light gas olefins such as ethylene, propylene, and butylene are important raw materials for multiple end products like polymers, rubbers, plastics, octane booster compounds, etc.

[0004] Benzene, toluene, and xylene are typically prepared by reforming naphtha such
20 as straight run naphtha from crude oil in a reformer. However, only a fraction (e.g. about 10 to 20 wt.%) of the crude oil is suitable for reforming and used to prepare benzene, toluene, and xylene. Further, although naphthenes are more favorable to form aromatics by reforming, typical reformer feed from crude oil has relatively low naphthene content. For example, typically less than 25 wt.% of the reformer feed is naphthenic. For example, see Turaga, et al.,
25 (2003). *Journal of Scientific and Industrial Research*, 62(10), 963-978; Mujtaba, et al., (2019). *Processes*, 7, 192.

[0005] Various attempts have been made to maximize aromatics production from crude oil. For example, processes having multiple hydrocracking units and other equipment have

been used. However such attempts may create additional problems arising from complexity of the process, decreased efficiency, and increased costs.

BRIEF SUMMARY OF THE INVENTION

[0006] A discovery has been made that provides a solution to at least one or more of the problems associated with producing high value chemicals such as C₆ to C₈ aromatics and/or light gas olefins from crude oil. In one aspect, a solution can include positioning a hydroprocessing unit upstream to a reforming unit used for producing aromatics. In some aspects, a single hydro processing unit can be used. The use of the upstream hydroprocessing unit can: i) increase the amount of reformer feed per unit crude oil processed; ii) increase the amount of naphthenes suitable for producing C₆ to C₈ aromatics by reforming; and/or iii) optionally increase the amount of steam cracker feed per unit crude oil processed. Further, use of the hydroprocessing unit can reduce the amount of olefins in the reformer feed, which can serve to reduce the exothermicity in the reforming unit, which can help conserve energy and increase the efficiency of the reforming unit. These advantages can be obtained by separating the product stream from the hydroprocessing unit into: (i) a stream comprising hydrocarbons having a boiling point less than 70 °C; (ii) a stream comprising hydrocarbons having a boiling point 70 °C to 140 °C; and (iii) a stream comprising hydrocarbons having a boiling point greater than 140 °C. The stream comprising hydrocarbons having a boiling point greater than 140 °C can be recycled back to the hydroprocessing unit. The stream comprising hydrocarbons having a boiling point 70 °C to 140 °C can be sent to the reformer unit to produce C₆ to C₈ aromatics (e.g., benzene, toluene, and/or xylene (BTX)). The stream comprising hydrocarbons having a boiling point less than 70 °C can be cracked (e.g., via steam cracking or catalytic cracking) to product light gas olefins.

[0007] In another aspect of the present invention, the use of the upstream hydroprocessing unit may not be used. In this aspect, C₆ to C₈ aromatics and/or light gas olefins can be produced from plastics (e.g., recycled mixed thermoplastic material) as a feed source. For example, the initial feed can include plastics (e.g., recycled mixed thermoplastic material). The plastics can be reactively extruded or melt cracked to form pyrolysis oil. The pyrolysis oil can be separated into: (i) a stream comprising hydrocarbons having a boiling point less than 70 °C; (ii) a stream comprising hydrocarbons having a boiling point 70 °C to 140 °C; and (iii) a stream comprising hydrocarbons having a boiling point greater than 140 °C. At least a portion of the stream comprising hydrocarbons having a boiling point greater than 140 °C can be

recycled back to the reactive extrusion or melt cracking process (e.g., the reaction process). The stream comprising hydrocarbons having a boiling point 70 °C to 140 °C can be sent to a reformer unit to produce C₆ to C₈ aromatics (e.g., BTX). The stream comprising hydrocarbons having a boiling point less than 70 °C or portions thereof can be, sent for steam reforming to produce hydrogen; or cracked in a catalytic cracking unit to produce light gas olefins; or sent to a gasoline pool; or any combination thereof. Benefits of this process include not using a hydroprocessing unit (although such a unit can be used in the context of the present invention) and/or the use of recycled plastics to efficiently produce BTX and optionally olefins. In some aspects, the stream containing hydrocarbons having a boiling point of 70 °C to 140 °C can contain chlorine, which can be beneficial in keeping the reformer catalyst active. In some aspects, at least a portion of the chloride present in the stream comprising hydrocarbons having a boiling point of 70 °C to 140 °C can be sourced from the plastics.

[0008] Certain aspects are directed to a first process for producing C₆ to C₈ aromatics and optionally light gas olefins. The first process can include any one of, any combination of, or all of the steps (a) to (e). In step (a) a first stream can be hydroprocessed to obtain a second stream. The first stream can contain hydrocarbons from crude oil and/or pyrolysis oil. The second stream can contain saturated hydrocarbons having boiling points less than 350 °C. In some aspects, at least 70 wt.% of the hydrocarbons in the second stream can be saturated hydrocarbons having boiling points less than 350 °C. In certain aspects, the second stream can further contain aromatics. In step (b) the second stream can be separated to obtain a third stream containing hydrocarbons having boiling point less than 70 °C, a fourth stream containing hydrocarbons having boiling point 70 °C to 140 °C, and a fifth stream containing hydrocarbons having boiling point greater than 140 °C. In step (c), at least a portion of the fifth stream can be recycled to the hydroprocessing step (a). In step (d), the fourth stream can be reformed to obtain a sixth stream containing C₆ to C₈ aromatics. The C₆ to C₈ aromatics can be benzene, toluene, and xylene, and the sixth stream can contain benzene, toluene, and xylene. Optionally, in step (e) the third stream can be cracked e.g. steam cracked or catalytically cracked to obtain light gas olefins. Reforming in step (d) can also produce non-aromatics and non C₆ to C₈ aromatics (e.g., aromatic hydrocarbons other than benzene, toluene, and xylene). In some aspects, a seventh stream containing at least a portion of the non-aromatics and non C₆ to C₈ aromatics produced in step (d) can be recycled to the hydroprocessing step (a). Optionally, a portion of the fifth stream can be cracked e.g. steam cracked or catalytically cracked with the third stream in step (e) to form the light gas olefins.

[0009] The hydroprocessing in step (a) can include hydrocracking and/or hydrotreating. In the hydrotreating process sulfur and/or nitrogen content of sulfur and/or nitrogen containing hydrocarbons can be reduced. The hydrocracking process can include cracking of hydrocarbons in the presence of H₂. In some aspects, the hydroprocessing can be performed at a low pressure, such as at a pressure equal to or lower than 100 barg. Without wishing to be bound by theory, it is believed that lower operating pressure may lead to less investment cost and may have a beneficial impact on the economics of the process. In some aspects, hydroprocessing conditions in step (a) can include a pressure of 30 barg to 100 barg; a temperature of 300 °C to 600 °C, preferably 350 °C to 500 °C; or weight hourly space velocity (WHSV) of 0.5 to 2 hr⁻¹; or any combinations thereof. In some aspects, the hydroprocessing can be performed in presence of hydrogen (H₂) with H₂ to hydrocarbon (e.g. H₂ and hydrocarbon fed to the hydroprocessing step) volume ratio of 200 Nm³/m³ to 2000 Nm³/m³. The hydroprocessing can be performed in presence of a catalyst. In some aspects, the catalyst can contain a hydrocracking catalyst and/or a hydrotreating catalyst. In some aspects, the hydrocracking catalyst can contain Ni and/or W. In some aspects, the hydrotreating catalyst can contain Co, Ni and/or Mo. In some aspects, the hydroprocessing can be performed in presence of a dissolved catalyst and/or a fixed bed catalyst. In some aspects, the dissolved catalyst can contain nickel (Ni) and/or molybdenum (Mo). In some aspects, the dissolved catalyst can contain metal naphthenates and/or octanoates. In some aspects, the dissolved catalyst can contain Ni octanoates, Ni naphthenates, Mo octanoates, or Mo naphthenates, or any combinations thereof. In some aspects, Ni octanoates, Ni naphthenates, Mo octanoates, and/or Mo naphthenates independently can be in a hydrocarbon base. In some aspects, the dissolved catalyst can be a catalyst solubilized in the feed and can form a homogeneous catalyst when mixed with feed (e.g. hydroprocessing feed). In some aspects, no additional solvent can be used for dissolving the catalysts e.g. metal naphthenates and/or octanoates in the feed. The fixed bed catalyst can contain one or more transition metal(s) on a support. In certain aspects, the one or more transition metal(s) can be cobalt (Co), Ni, Mo and/or tungsten (W). In certain aspects, the fixed bed catalyst can contain Co and Mo on a support; Ni and Mo on a support; Co, Ni, and Mo on a support; Ni and W on a support; or Ni, W, and Mo on a support, or any combinations thereof. In some aspects, the fixed bed catalyst support can be alumina, silica, aluminosilicates or zeolite, or any combinations thereof. The zeolite can be a X-type zeolite, Y-type or USY-type zeolite, mordenite, faujasite, nano-crystalline zeolite, MCM mesoporous material, SBA-15, silico-alumino phosphate, gallophosphate, titanophosphate, ZSM-5, ZSM-11, ferrierite, heulandite, zeolite-A, erionite, and chabazite, or any combinations thereof.

[0010] In some aspects, the second stream can be separated into the third, fourth and fifth stream in step (b) by atmospheric distillation with boiling points cuts of 70 °C and 140 °C. The third stream can contain a hydrocarbon fraction with upper boiling point cut of 70 °C, from the second stream. The fourth stream can contain a hydrocarbon fraction with lower boiling point cut of 70 °C and an upper boiling point cut of 140 °C, from the second stream. The fifth stream can contain a hydrocarbon fraction with lower boiling point cut of 140 °C, from the second stream.

[0011] The first stream can be obtained from crude oil. In some aspects, the first stream can be obtained by atmospheric distillation of i) crude oil, or ii) crude oil and pyrolysis oil. The atmospheric distillation can be performed in a crude distillation unit (CDU), with boiling points cut of 70 °C and 140 °C. From the CDU, a first hydrocarbon fraction having upper boiling point cut of 70 °C, a second hydrocarbon fraction having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C, and a third hydrocarbon fraction having lower boiling point cut of 140 °C, can be obtained. In some aspects, the third hydrocarbon fraction can form the first stream and can be hydroprocessed e.g. in step (a). The second hydrocarbon fraction can be reformed to form C₆ to C₈ aromatics. In certain aspects, an eighth stream containing the second hydrocarbon fraction can be reformed in step (d) with the fourth stream, to form the sixth stream and seventh stream. In some aspects, the first hydrocarbon fraction or a portion of the first hydrocarbon fraction can be cracked e.g. steam cracked or catalytically cracked to form light gas olefins. In some aspects, the first hydrocarbon fraction or a portion of the first hydrocarbon fraction can be hydroprocessed. In certain aspects, crude oil can be distilled in the CDU, and a ninth stream containing the first hydrocarbon fraction can optionally be cracked e.g. steam cracked or catalytically cracked in step (a) with the third stream, to form light gas olefins. In certain aspects, crude oil and pyrolysis oil can be distilled in the CDU, and a ninth stream containing the first hydrocarbon fraction can be hydroprocessed in step (a) with the first stream, to form the second stream. In some aspects, the pyrolysis oil can be obtained from plastics by reactive extrusion or by melt cracking, and can contain chlorides and olefins.

[0012] In some aspects, the first stream can contain condensate, naphtha, light crude oil, or a crude oil hydrocarbon fraction having an upper boiling point cut of 350 °C, whole crude oil, or any combinations thereof. In some aspects, the first stream can contain pyrolysis oil. The pyrolysis oil can be obtained from plastics by reactive extrusion or by melt cracking. The reactive extrusion or melt cracking of the plastics can include depolymerizing the plastics

at a depolymerization temperature sufficient to produce a hydrocarbonaceous wax stream, and catalytic cracking of the hydrocarbonaceous wax stream in presence of a cracking catalyst under cracking conditions sufficient to produce the pyrolysis oil, wherein the cracking conditions can include a cracking temperature that is lower than, equal to, or higher than the depolymerization temperature. In some aspects, the depolymerization of the plastic can be performed in an extruder/twin screw reactor/auger.

[0013] Certain aspects are directed to a second process for producing C₆ to C₈ aromatics and optionally light gas olefins. The second process can include any one of, any combination of, or all of steps (i), (ii), and (iii). In step (i) reactive extrusion or melt cracking of plastics can be performed to obtain pyrolysis oil. In step (ii), the pyrolysis oil can be separated to obtain a stream A containing hydrocarbons having boiling point less than 70 °C, a stream B containing hydrocarbons having boiling point 70 °C to 140 °C, and a stream C containing hydrocarbons having boiling point greater than 140 °C. In step (iii), the stream B can be reformed to obtain a stream D containing C₆ to C₈ aromatics. The C₆ to C₈ aromatics can be benzene, toluene and xylene and the stream D can contain benzene, toluene, and xylene. In some aspects, the stream A can be sent to a gasoline pool. The reactive extrusion or melt cracking of the plastics can include depolymerizing the plastics at a depolymerization temperature sufficient to produce a hydrocarbonaceous wax stream, and catalytic cracking of the hydrocarbonaceous wax stream in presence of a cracking catalyst under cracking conditions sufficient to produce the pyrolysis oil, wherein the cracking conditions can include a cracking temperature that is lower than, equal to, or higher than the depolymerization temperature. In some aspects, the depolymerization of the plastics can be performed in an extruder/twin screw reactor/auger. The pyrolysis oil can be separated into the streams A, B, and C by atmospheric distillation with boiling points cuts at 70 °C and 140 °C. The stream A can contain a hydrocarbon fraction with upper boiling point cut of 70 °C, from the pyrolysis oil. The stream B can contain a hydrocarbon fraction with lower boiling point cut of 70 °C and an upper boiling point cut of 140 °C, from the pyrolysis oil. The C stream can contain a hydrocarbon fraction with lower boiling point cut of 140 °C, from the pyrolysis oil. In certain aspects, the stream C can be recycled to the hydrocarbonaceous wax catalytic cracking step. Reforming in step (iii) can also produce non-aromatics and non C₆ to C₈ aromatics (e.g. aromatic hydrocarbons other than benzene, toluene and xylene). In some aspects, a stream E containing at least a portion of the non-aromatics and non C₆ to C₈ aromatics produced during reforming can be recycled to the hydrocarbonaceous wax catalytic cracking step. In some aspects, a stream F containing a portion of a hydrogen

(H₂) containing gas from the reforming step (iii) can be recycled to the hydrocarbonaceous wax catalytic cracking step.

[0014] The reforming (e.g., in step (d) of the first process and in step (iii) of the second process) can be performed with processes and systems known in the art. In some aspects, the reforming conditions can include a temperature of 400 °C to 600 °C, preferably 450 °C to 550 °C, and/or a pressure of 2 barg to 30 barg. The reforming can be performed in presence of H₂. In some aspects, H₂ to hydrocarbon (e.g., H₂ and hydrocarbon fed to the reforming step) mole ratio during reforming can be 2:1 and 9:1. The reforming can be performed in presence of a reforming catalyst. The reforming catalyst can be a reforming catalyst known in the art. In some aspects, the reforming catalyst can contain platinum (Pt) and rhenium (Re) on alumina, Pt on alumina, metal loaded zeolite, or any combinations thereof. The metal loaded zeolite can contain one or more dehydrogenating metal(s) including but not limited to Pt, palladium (Pd), gallium (Ga) and/or nickel (Ni). The reforming process can be semi-regenerative reforming process or continuous catalytic reforming process, and the reforming can be performed in a semi-regenerative reformer unit or continuous catalytic reformer unit.

[0015] The cracking (e.g., in optional step (e) of the first process) can be steam cracking or catalytically cracking. In some aspects, the steam cracking can be performed using dilution steam, with processes and systems known in the art. In certain aspects, the steam cracking conditions can include a temperature of 750 °C to 900 °C, a pressure of atmospheric pressure to 6 barg, at residence time of 50 ms to 1 s or less, or any combinations thereof. In some aspects, the catalytic cracking can be performed in a fluidized bed catalytic cracking (FCC) unit or a fixed bed catalytic cracking unit. In certain aspects, the catalytic cracking conditions can include a temperature of 500 °C to 800 °C, a pressure of atmospheric pressure to 10 barg, a contact time of less than 5s, or any combinations thereof.

[0016] In some aspects, the plastics from which the pyrolysis oil (e.g., pyrolysis oil used in the first process and/or second process) is produced, can be obtained from plastic containing waste, such as post-consumer plastic containing waste. In certain aspects, the plastics can contain chlorides and at least a portion of the chlorides can be sent to the reforming step (e.g., step (d) of the first process and step (iii) of the second process) through the process steps described herein. The chloride can increase the activity of the reforming catalyst. In certain aspects, chloride can be fed to the reforming step (e.g., to step (d) of the first process and to step (iii) of the second process) at a concentration 0.1 ppm to 15 ppm.

[0017] The following includes definitions of various terms and phrases used throughout this specification.

[0018] The terms “about” or “approximately” are defined as being close to as understood by one of ordinary skill in the art. In one non-limiting embodiment the terms are
5 defined to be within 10%, preferably, within 5%, more preferably, within 1%, and most preferably, within 0.5%.

[0019] The terms “wt.%”, “vol.%” or “mol.%” refer to a weight, volume, or molar percentage of a component, respectively, based on the total weight, the total volume, or the total moles of material that includes the component. In a non-limiting example, 10 moles of
10 component in 100 moles of the material is 10 mol.% of component.

[0020] The term “substantially” and its variations are defined to include ranges within 10%, within 5%, within 1%, or within 0.5%.

[0021] The terms “inhibiting” or “reducing” or “preventing” or “avoiding” or any variation of these terms, when used in the claims and/or the specification, include any
15 measurable decrease or complete inhibition to achieve a desired result.

[0022] The term “effective,” as that term is used in the specification and/or claims, means adequate to accomplish a desired, expected, or intended result.

[0023] The use of the words “a” or “an” when used in conjunction with the term “comprising,” “including,” “containing,” or “having” in the claims or the specification may
20 mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.”

[0024] The words “comprising” (and any form of comprising, such as “comprise” and “comprises”), “having” (and any form of having, such as “have” and “has”), “including” (and any form of including, such as “includes” and “include”) or “containing” (and any form of
25 containing, such as “contains” and “contain”) are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

[0025] The process of the present invention can “comprise,” “consist essentially of,” or “consist of” particular ingredients, components, compositions, etc., disclosed throughout the specification.

[0026] Other objects, features and advantages of the present invention will become apparent from the following figures, detailed description, and examples. It should be understood, however, that the figures, detailed description, and examples, while indicating specific embodiments of the invention, are given by way of illustration only and are not meant to be limiting. Additionally, it is contemplated that changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. In further embodiments, features from specific embodiments may be combined with features from other embodiments. For example, features from one embodiment may be combined with features from any of the other embodiments. In further embodiments, additional features may be added to the specific embodiments described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] For a more complete understanding, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0028] **FIG. 1** is a schematic of an example of the present invention to produce C₆ to C₈ aromatics and optionally light gas olefins.

[0029] **FIG. 2** is a schematic of an embodiment of the present invention to produce C₆ to C₈ aromatics and optionally light gas olefins using the system of FIG. 1, system 100.

[0030] **FIG. 3** is a schematic of a second embodiment of the present invention to produce C₆ to C₈ aromatics and optionally light gas olefins using the system of FIG. 1, system 100.

[0031] **FIG. 4** is a schematic of a third embodiment of the present invention to produce C₆ to C₈ aromatics and optionally light gas olefins using the system of FIG. 1, system 100.

[0032] **FIG. 5** is a schematic of a second example of the present invention to produce C₆ to C₈ aromatics and optionally light gas olefins.

DETAILED DESCRIPTION OF THE INVENTION

[0033] A discovery has been made that provides a solution to at least some of the problems associated with producing high value chemicals such as C₆ to C₈ aromatics and/or light gas olefins from crude oil. The solution can include using a hydroprocessing unit

configured to hydroprocess hydrocarbons at a pressure below 100 barg. The hydroprocessing unit can be positioned upstream to a reformer used for producing aromatics and/or to a cracking unit e.g. a steam cracker or catalytic cracking unit used for producing light olefins. As shown in a non-limiting manner in the examples and Figures, use of the upstream hydroprocessing unit can increase naphthenic content of the reformer feed, such as to 30 wt.% or above, increase the mono aromatics in reformer feed, and/or enrich the reformer feed for producing aromatics especially C₆ to C₈ aromatics. In some aspects, the higher aromatics (2 rings or higher, or aromatics with side chain) can be converted to mono aromatics or naphthenes in the hydroprocessing unit, increasing naphthenic content of the reformer feed. Use of the upstream hydroprocessing unit also increases the amount of hydrocarbon being reformed, and decrease olefin content in the reformer feed. In some aspects, amount of hydrocarbon being reformed can be increased by increasing the amount of 70 to 140 °C boiling stream which can be fed to the reformer through upgrading of heavy ends of crude oil at the hydroprocessing unit.

[0034] In another aspect of the present invention, the use of the upstream hydroprocessing unit may not be used. In this aspect, C₆ to C₈ aromatics and optionally light gas olefins can be produced from pyrolysis oil obtained from plastics, such as waste plastics. Benefits of this process include the use of recycled plastics to efficiently produce BTX and optionally olefins.

[0035] These and other non-limiting aspects of the present invention are discussed in further detail in the following sections with reference to the figures. The units shown in the figures can include one or more heating and/or cooling devices (e.g., insulation, electrical heaters, jacketed heat exchangers in the wall) or controllers (e.g., computers, flow valves, automated valves, etc.) that can be used to control temperatures and pressures of the processes. While only one unit is usually shown, it should be understood that multiple units can be housed in one unit. In some aspects, a reactor shown or described unless otherwise mentioned can be a fixed bed reactor, moving bed reactor, trickle-bed reactor, rotating bed reactor, slurry reactor or fluidized bed reactor.

[0036] Referring to FIG. 1, a system and process for producing C₆ to C₈ aromatics and optionally light gas olefins according to one example of the present invention is described. The system 100 can include a hydroprocessing unit 120, a separation unit 122, a reforming unit 124 and an optional cracking unit 126. The optional cracking unit 126 can be steam cracking unit or a catalytic cracking unit. A first stream 101 containing hydrocarbons from crude oil and/or

pyrolysis oil can be fed to the hydroprocessing unit 120. In the hydroprocessing unit 120 the first stream 101 can be hydroprocessed to obtain a hydroprocessed product. A second stream 102 containing the hydroprocessed product can exit the hydroprocessing unit 120 and can be fed to the separation unit 122. In the separation unit 122 the second stream can be separated into a third stream 103, a fourth stream 104, and a fifth stream 105. The third stream 103 can contain a hydrocarbon fraction having an upper boiling point cut of 70 °C. The fourth stream 104 can contain a hydrocarbon fraction having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C. The fifth stream 105 can contain a hydrocarbon fraction having lower boiling point cut of 140 °C. In certain aspects, the third stream 103 can be fed to the optional cracking unit 126 and can be cracked e.g. via steam cracking or catalytic cracking to form light gas olefins. A light gas olefins stream 127 containing the light gas olefins can exit the cracking unit 126. At least a portion of the fifth stream 105 can be recycled to the hydroprocessing unit 120 and can be hydroprocessed. Optionally a portion of the fifth stream 105 can be sent to the cracking unit 126 and can be cracked e.g. via steam cracking or catalytic cracking to produce light gas olefins. The third stream 103 and the optional fifth stream portion can be fed to cracking unit 126 as separate streams or can be combined and fed as a combined stream (not shown). The fourth stream 104 can be fed to the reforming unit 124 and reformed to form C₆ to C₈ aromatics. A sixth stream 106 containing C₆ to C₈ aromatics can exit the reforming unit 124. Reforming in the reforming unit 124 can also produce non-aromatics and non-C₆ to C₈ aromatics (e.g. aromatics other than C₆ to C₈ aromatics). A seventh stream 107 containing at least a portion of the non-aromatics and non- C₆ to C₈ aromatics from the reforming unit 124 can be recycled to the hydroprocessing unit 120 and can be hydroprocessed.

[0037] In certain aspects, the first stream 101 can be obtained by atmospheric distillation of crude oil. Referring to FIG. 2, a system and process for producing C₆ to C₈ aromatics and optionally light gas olefins using the system 100 according to one embodiment of the present invention is described. The system 200 can include a crude distillation unit (CDU) 230 and the system 100. A stream 232 containing crude oil can be fed to the CDU 230. In the CDU 230, the crude oil can be separated through atmospheric distillation to form the first stream 101, an eighth stream 208 and a ninth stream 209. The first stream 101, in system 200, can contain a hydrocarbon fraction having lower boiling point cut of 140 °C, separated from crude oil in the CDU 230. The first stream can be fed to the hydroprocessing unit 120 of the system 100, and can be processed in the system 100 as described above, e.g., for FIG. 1. The eighth stream 208 can contain a hydrocarbon fraction having lower boiling point cut of 70

- °C and upper boiling point cut of 140 °C, separated from crude oil in the CDU 230. The eight stream 208 can be fed to the reforming unit 124 of the system 100, and can be reformed to obtain C₆ to C₈ hydrocarbons. The eighth stream 208 and the fourth stream 104 can be fed to the reforming unit 124 separately or as a combined stream. The ninth stream 209 can contain
- 5 a hydrocarbon fraction having upper boiling point cut of 70 °C, separated from crude oil in the CDU 230. In some aspects, the ninth stream 209 can be fed to the optional cracking unit 126 of the system 100, and can be cracked e.g. via steam cracking or catalytic cracking to obtain light gas olefins. The ninth stream 209, the third stream 103, optional fifth stream portion can be fed to the optional cracking unit 126 separately or at any combinations.
- 10 **[0038]** In certain aspects, the first stream 101 can be obtained by atmospheric distillation of crude oil and pyrolysis oil. The pyrolysis oil can be plastic pyrolysis oil, e.g., can be obtained from plastics. Referring to FIG. 3, a system and process for producing C₆ to C₈ aromatics and optionally light gas olefins using system 100 according to a second embodiment of the present invention is described. The system 300 can include a plastics
- 15 depolymerization unit 342, a catalytic cracking unit 344, a CDU 330, and the system 100. Pyrolysis oil can be produced from plastics using the plastics depolymerization unit 342 and the catalytic cracking unit 344. Plastics 346 can be fed to the plastic depolymerization unit 342. In the plastics depolymerization unit 342 plastics can be depolymerized to form hydrocarbonaceous wax. The hydrocarbonaceous wax 348 from the depolymerization unit 342
- 20 can be fed to the catalytic cracking unit 344. In the catalytic cracking unit 344 the hydrocarbonaceous wax can be cracked in presence of a cracking catalyst to produce the pyrolysis oil. The pyrolysis oil 350 from the catalytic cracking unit 344, and a stream 332 containing crude oil can be fed to the CDU 330. The pyrolysis oil and crude oil can be fed to the CDU as separate feeds or as a combined feed. In the CDU 330, crude oil and pyrolysis oil
- 25 mixture can be separated through atmospheric distillation to form the first stream 101, an eighth stream 308 and a ninth stream 309. The first stream 101, in system 300, can contain a hydrocarbon fraction having lower boiling point cut of 140 °C, separated from crude oil and pyrolysis oil mixture in the CDU 330. The first stream 101 can be fed to the hydroprocessing unit 120 of the system 100, and can be processed in the system 100 as described above, e.g.,
- 30 for FIG. 1. The eighth stream 308 can contain a hydrocarbon fraction having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C, separated from crude oil and pyrolysis oil in the CDU 330. The eighth stream 308 can be fed to the reforming unit 124 of the system 100 and can be reformed to obtain C₆ to C₈ hydrocarbons. The eighth stream 308 and the fourth

stream 104 can be fed to the reforming unit 124 separately or as a combined stream. The ninth stream 309 can contain a hydrocarbon fraction having upper boiling point cut of 70 °C, separated from crude oil and pyrolysis oil in the CDU 330. The ninth stream 309 can be fed to the hydroprocessing unit 120 of the system 100. The ninth stream 309 and the first stream 101
5 can be fed to the hydroprocessing unit 120 separately or as a combined feed. In an alternative embodiment, the plastics depolymerization unit 342, and the catalytic cracking unit 344 are not a part of the system 300, and pyrolysis oil, e.g. produced using a separate system and process, along with crude oil can be fed to the CDU.

[0039] Through use of the hydroprocessing unit 120, additional C₆ to C₈ aromatics
10 and/or light gas olefins can be produced from hydrocarbon fractions (from crude oil and/or pyrolysis oil) having lower boiling point cut of 140 °C, whereas such the hydrocarbon fractions are typically not used for reforming.

[0040] In certain aspects, the first stream 101 can contain pyrolysis oil. The pyrolysis oil can be plastic pyrolysis oil, e.g., can be obtained from plastics. Referring to FIG. 4, a system
15 and process for producing C₆ to C₈ aromatics and optionally light gas olefins using system 100 according to a third embodiment of the present invention is described. The system 400 can include a plastics depolymerization unit 442, a catalytic cracking unit 444, and the system 100. Pyrolysis oil can be produced from plastics using the plastics depolymerization unit 442 and the catalytic cracking unit 444. Plastics 446 can be fed to the plastics depolymerization unit
20 442. In the plastics depolymerization unit 442, plastics can be depolymerized to form hydrocarbonaceous wax. The hydrocarbonaceous wax 448 from the depolymerization unit 442 can be fed to the catalytic cracking unit 444. In the cracking unit 444, the hydrocarbonaceous wax can be cracked in presence of a cracking catalyst to produce the pyrolysis oil. The pyrolysis oil from catalytic cracking unit 444 can be fed to the system 100, via stream 101 and
25 can be processed as described above, e.g., in FIG. 1.

[0041] Referring to FIG. 5, system and process for producing C₆ to C₈ aromatics and optionally light gas olefins according to another example of the present invention is described. System 500 can include a plastics depolymerization unit 502, a catalytic cracking unit 504, a separation unit 506, and a reforming unit 508. Plastics 501 can be fed to the plastic
30 depolymerization unit 502. In the depolymerization unit 502, plastics can be depolymerized to form hydrocarbonaceous wax. The hydrocarbonaceous wax 503 from the depolymerization unit 502 can be fed to the catalytic cracking unit 504. In the catalytic cracking unit 504, the

hydrocarbonaceous wax can be cracked in presence of a cracking catalyst to produce pyrolysis oil. A stream 505 containing the pyrolysis oil from the catalytic cracking unit 504 can be fed to the separation unit 506. In the separation unit 506, the stream 505 can be separated into a stream A 510, a stream B 511, and a stream C 512. The stream A 510 can contain a hydrocarbon fraction having upper boiling point cut of 70 °C, separated from pyrolysis oil in the separation unit 506. The stream B 511 can contain a hydrocarbon fraction having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C, separated from pyrolysis oil in the separation unit 506. The stream C 512 can contain a hydrocarbon fraction having lower boiling point cut of 140 °C, separated from pyrolysis oil in the separation unit 506. The stream C 512 can be recycled to the catalytic cracking unit 504 and can be catalytically cracked to produce pyrolysis oil. The stream B 511 can be fed to the reforming unit 508 and can be reformed to obtain C₆ to C₈ aromatics. A stream D 513 containing C₆ to C₈ aromatics can exit the reforming unit 508. Reforming in the reforming unit 508 can also produce non-aromatics and non- C₆ to C₈ aromatics (e.g. aromatics other than C₆ to C₈ aromatics). A stream E 514 containing at least a portion of the non-aromatics and non- C₆ to C₈ aromatics from the reforming unit 508 can be recycled to the catalytic cracking unit 504 and can be catalytically cracked to produce pyrolysis oil. A stream F 515 containing H₂ containing gas from the reforming unit 508 can be recycled to the catalytic cracking unit 504. The H₂ containing gas from the reforming unit can contain at least a portion of the H₂ added and/or H₂ produced during reforming. In some aspects, the stream A 510 can be sent to and/or mixed with a gasoline pool, e.g. gasoline pool of a refinery.

[0042] Hydroprocessing in the hydroprocessing unit 120 can include hydrotreating, and/or hydrocracking of the feed. The hydrocarbon feed (e.g., introduced via streams 101, 105, 107, and/or 309) in the unit 120 can be hydroprocessed in presence of a dissolved catalyst and a fixed bed catalyst to form the hydroprocessed product. Hydroprocessing in the unit 120 can be performed at a low pressure, such as at a pressure below 100 barg. In some aspects, the hydroprocessing conditions in unit 120 can include: i) a pressure of 30 barg to 100 barg, or at least any one of, equal to any one of, or between any two of 30, 40, 50, 60, 70, 80, 90 and 100 barg; ii) a temperature 300 °C to 600 °C, preferably 350 °C to 500 °C, or at least any one of, equal to any one of, or between any two of 300, 350, 400, 450, 500, 550 and 600 °C; or iii) a weight hourly space velocity (WHSV) of 0.5 to 2 hr⁻¹, or at least any one of, equal to any one of, or between any two of 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, and 2 hr⁻¹, or any combinations thereof. Hydroprocessing can be performed in presence of

hydrogen (H₂). H₂ can be fed to the hydroprocessing unit 120 via one or more of the hydrocarbon feed streams (e.g., 101, 105, 107, and/or 309) and/or separately. In some aspects, H₂ and hydrocarbon (e.g., introduced via stream(s) 101, 105, 107, and/or 309) can be fed to the hydroprocessing unit 120 at volume ratio of 200 Nm³:1 m³ to 2000 Nm³:1 m³, or at least any one of, equal to any one of, or between any two of 200:1, 300:1, 400:1, 500:1, 600:1, 700:1, 800:1, 900:1, 1000:1, 1100:1, 1200:1, 1300:1, 1400:1, 1500:1, 1600:1, 1700:1, 1800:1, 1900:1, and 2000:1 Nm³: m³. In some aspects, the dissolved catalyst can contain Ni and/or Mo. In some aspects, the dissolved catalyst can contain metal octanoates, and/or naphthenates. In some aspects, the dissolved catalyst can contain Ni octanoates, Ni naphthenates, Mo octanoates, or Mo naphthenates, or any combinations thereof. In some aspects, Ni octanoates, Ni naphthenates, Mo octanoates, and/or Mo naphthenates independently can be in a hydrocarbon base. In some aspects, the dissolved catalyst can be a catalyst solubilized in the feed and can form a homogeneous catalyst when mixed with feed (e.g. hydroprocessing feed). In some aspects, no additional solvent can be used for dissolving the catalysts e.g. metal naphthenates and/or octanoates in the feed. The metal octanoates and/or naphthenates can be present in a liquid hydrocarbon of the feed, as dissolved organic salts.

[0043] The fixed bed catalyst can include Co, Ni, Mo and/or W on a support. In certain aspects, the fixed bed catalyst can contain Co and Mo on a support; Ni and Mo on a support; Co, Ni, and Mo on a support; Ni and W on a support; or Ni, W, and Mo on a support, or any combinations thereof. In some aspects, the fixed bed catalyst support can be alumina, silica, aluminosilicates or zeolite or any combinations thereof. The zeolite can be a X-type zeolite, Y-type or USY-type zeolite, mordenite, faujasite, nano-crystalline zeolite, MCM mesoporous material, SBA-15, silico-alumino phosphate, gallophosphate, titanophosphate, ZSM-5, ZSM-11, ferrierite, heulandite, zeolite-A, erionite, and chabazite, or any combinations thereof.

[0044] In the reforming unit (e.g., 124 and/or 508), hydrocarbons can be reformed to form C₆ to C₈ aromatic hydrocarbons, such as benzene, toluene, and xylene. In some aspects, the reforming conditions in unit (e.g., 124 and/or 508) can include a temperature of 400 °C to 600 °C, preferably 450 °C to 550 °C, or at least any one of, equal to any one of, or between any two of 400, 450, 500, 550, and 600 °C and/or a pressure of 2 barg to 30 barg or at least any one of, equal to any one of, or between any two of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and 30 barg. Reforming can be performed in presence of H₂. H₂ can be fed to the reforming unit, through the one or more hydrocarbon feed streams to the reforming unit (e.g., stream 104

for unit 124; stream 511 for unit 508), and/or separately. In some aspects, the H₂ and hydrocarbons can be fed to the reforming unit at a mole ratio of 2:1 to 9:1 or at least any one of, equal to any one of, or between any two of 2:1, 3:1, 4:1, 5:1, 6:1, 7:1, 8:1, and 9:1. Reforming can be performed in presence of a reforming catalyst. In some aspects, the reforming catalyst can contain Pt and Re on alumina; Pt on alumina; metal loaded zeolite; or any combinations thereof. The metal loaded zeolite can contain one or more dehydrogenating metal including but not limited to Pt, Pd, Ga and/or Ni. Reforming in units 124, 508 can be performed according to systems and processes known in the art. The reforming process can be semi-regenerative reforming process or continuous catalytic reforming process, and reforming unit (e.g., 124 and/or 508) can be a semi-regenerative reforming unit or a continuous catalytic reforming unit. The reforming catalyst can be included in the semi-regenerative reforming unit as fixed bed catalyst and in the continuous catalytic reformer unit as a moving bed catalyst. The reforming catalyst can be regenerated according to methods known in the art. In some aspects, the reforming unit (e.g., 124 and/or 508), can include multiple reactors, such as 3 or more reactors. The hydrocarbon feed to the reactors can be heated prior to feeding to the reactors.

[0045] The optional cracking unit 126, can be a steam cracking unit or a catalytic cracking unit. The hydrocarbon feed to the cracking unit 126 (e.g., introduced via streams 103, 209, optional portion of 105 to unit 126) can be cracked, e.g. via steam cracking or catalytic cracking to form light gas olefins. In some aspects, the light gas olefins can include ethylene, propylene and/or butylene. In some aspects, the hydrocarbon feed can be steam cracked in presence of steam, such as dilution steam. In certain aspects, the steam cracking conditions in the cracking unit 126 can include i) a temperature of 750 °C to 900 °C or at least any one of, equal to any one of, or between any two of 750, 775, 800, 825, 850, 875 and 900 °C; ii) a pressure of atmospheric pressure to 6 barg, or at least any one of, equal to any one of, or between any two of atmospheric pressure, 2 barg, 3 barg, 4 barg, 5 barg and 6 barg; iii) or a residence time of 0.05 s to 1 s, or at least any one of, equal to any one of, or between any two of 0.05, 0.08, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1 s; or any combinations thereof. In certain aspects, the catalytic cracking conditions in the cracking unit 126 can include i) a temperature of 500 °C to 800 °C, or at least any one of, equal to any one of, or between any two of 500, 525, 550, 575, 600, 625, 650, 675, 700, 725, 750, 775, and 800 °C; ii) a pressure of atmospheric pressure to 10 barg or at least any one of, equal to any one of, or between any

two of atmospheric pressure, 2 barg, 3 barg, 4 barg, 5 barg, 6 barg, 7 barg, 8 barg, 9 barg and 10 barg; iii) a contact time of less than 5s; or any combinations thereof.

[0046] Pyrolysis oil can be produced by reactive extrusion/melt cracking of plastics, using the plastics depolymerization unit (e.g., 342, 442, and/or 502) and the catalytic cracking unit (e.g., 344, 444, and/or 504). In some aspects, the plastics feed (e.g., 346, 446, and/or 501) can be a mixed plastic feed, and can contain one or more of polyolefins (e.g., polyethylenes, ethylene alpha-olefin copolymers, polypropylenes or like), polystyrenes, polyesters (e.g., poly alkylene terephthalates), polyvinyl chloride, and polyamides (e.g., nylon, polyphthalamides or like). The plastics can be obtained from plastics containing waste, such as plastics containing post-consumer waste.

[0047] In the plastics depolymerization unit (e.g., 342, 442, and/or 502) the plastic feed can be depolymerized to form hydrocarbonaceous wax. The average molecular weight of the hydrocarbonaceous wax (e.g., of the compounds in the hydrocarbonaceous wax) can be at least 50 times lower, such as 20 to 50 times lower than the average molecular weight of the plastic feed (e.g., of the compounds in the plastic feed). In some aspects, the depolymerization can be performed in presence of a catalyst. The catalyst can include a liquid catalyst and/or a solid catalyst. In some particular aspects, the liquid catalyst can contain one or more organometallic compounds, such octanoates and/or naphthenates of a transition metal, such as Ni, Mo, Co, or W. In some aspects, the liquid catalyst can be a catalyst dissolved in the plastic melt. In some aspects, the liquid catalyst can be a homogeneous catalyst in the plastic melt. The solid catalyst can contain an inorganic oxide, aluminosilicate, zeolite, MCM mesoporous material, SBA-15, a silico-alumino phosphate, gallium phosphate, titanophosphate, or a molecular sieve, or combinations thereof. The zeolite can be ZSM-5, an X-type zeolite, a Y-type zeolite, a USY-zeolite, mordenite, faujasite, or nano-crystalline zeolite, or any combinations thereof. In some aspects, the solid catalyst can be a heterogeneous catalyst in the plastic melt. In some aspects, the solid catalyst can remain in solid state in the plastic melt. In some aspects, the depolymerization unit (342, 442, and/or 502) can include an extruder. The plastics and catalysts can be fed to the extruder using one or more feeders, e.g., from a throat hopper and/or any side feeders. The plastics and catalysts can be fed to the extruder, e.g., to a barrel of the extruder, separately or at any combinations, e.g., blended combinations. The extruder can have a single screw, left handed screw, right handed screw, neutral screw, kneading screw, multiple screws, intermeshing co-rotating or counter rotating screws, non-intermeshing co-rotating or

counter rotating screws, reciprocating screws, screws with pins, screws with screens, barrels with pins, rolls, rams, helical rotors, co-kneaders, disc-pack processors, various other types of extrusion equipment, or combinations comprising at least one of the foregoing. The plastics feed in the extruder barrel can be heated with one or more heaters arranged along the length of the extruder barrel. In the extruder barrel the plastics feed can be heated, melted, and depolymerized to form the hydrocarbonaceous wax. In some aspects, the plastics feed in the extruder barrel can be depolymerized at a temperature of 300 to 500 °C, or at least any one of, equal to any one of, or between any two of 300, 320, 340, 360, 380, 400, 420, 440, 460, 480, and 500 °C. The residence time of the plastics in the extruder can be less than an hour such as 1 min to 15 min. In certain aspects, the extruder can contain one or more vents configured to introduce and/or withdraw one or more gases into and/or from the extruder barrel. The plastic melt and/or hydrocarbonaceous wax can be extruded from the extruder through a die. The hydrocarbonaceous wax from the extruder of the depolymerization unit can be fed to the catalytic cracking unit.

[0048] In the catalytic cracking unit (e.g., 344, 444, and/or 504) the hydrocarbonaceous wax can be catalytically cracked in presence of a cracking catalyst to form pyrolysis oil. In some aspects, the cracking catalyst can contain a zeolite and/or a metal loaded zeolite. In some particular aspects, the zeolite can be ZSM-5. In certain aspects, metal can be a transition metal, such as Mg, Ni, and/or Co. The hydrocarbonaceous wax in the catalytic cracking unit (e.g., 344, 444, and/or 504) can be catalytically cracked in a fixed bed reactor or a fluidized bed reactor. In certain aspects, the catalytic cracking of the hydrocarbonaceous wax (e.g., in the catalytic cracking unit 344, 444, and/or 504) can be performed at a temperature lower than, equal to, or higher than the temperature at which plastics feed was depolymerized to form the hydrocarbonaceous wax (e.g., in the depolymerization unit 342, 442, and/or 502). In certain aspects, the catalytic cracking conditions in the catalytic cracking unit 344, 444, and/or 504 can include a temperature of 350 to 500 °C, or at least any one of, equal to any one of, or between any two of 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, and 500 °C, a pressure of 1 to 6 bara, or any combinations thereof. In some aspects, the average molecular weight of the pyrolysis oil (e.g., of the compounds in the pyrolysis oil) can be at least 3 times lower than the average molecular weight of the hydrocarbonaceous wax (e.g., of the compounds in the hydrocarbonaceous wax). The pyrolysis oil can contain paraffins, isoparaffins, olefins, naphthenes, and aromatic hydrocarbons.

[0049] In certain aspects, the plastics feed can contain chloride containing plastics such as polyvinyl chloride. In some aspects, a portion of the chlorides from the plastics feed can be fed to the reformer unit (e.g., 124 and/or 508) through the process steps described herein. The chloride can increase the activity of the reforming catalyst. In certain aspects, chloride can be fed to the reformer unit 124, 508 at a concentration of 0.1 ppm to 15 ppm, or at least any one of, equal to any one of, or between any two of 0.1, 1, 2, 4, 6, 8, 10, 12, 14 and 15 ppm.

[0050] The second stream 102 can contain saturated hydrocarbons having boiling point less than 350 °C. In some aspects, at least 70 wt.% of the hydrocarbons in the second stream 102 can be saturated hydrocarbons having boiling point less than 350 °C. In some aspects, the second stream can contain: i) 10 wt.% to 40 wt.%, or at least any one of, equal to any one of, or between any two of 10, 15, 20, 25, 30, 35, and 40 wt.% of naphthenes; ii) 2 wt.% to 20 wt.%, or at least any one of, equal to any one of, or between any two of 2, 3, 4, 6, 8, 10, 12, 14, 16, 18 and 20 wt.% of aromatics; and iii) paraffins and isoparaffins with total concentration of 50 to 85 wt.% or at least any one of, equal to any one of, or between any two 50, 55, 60, 65, 70, 75, 80 and 85 wt.%, based on the total weight of the second stream. In some aspects, the olefin content of the second stream 102 can be less than 8 wt.%, or less than 5 wt.%, or less than 3 wt.%, or less than 1 wt.%, or the second stream can be essentially free of olefins. Naphthenes described herein can include branched and non-branched naphthenes.

[0051] The fourth stream 104 and the stream B 511 can contain hydrocarbons having boiling points from 70 °C to 140 °C. The fourth stream 104 can contain: i) 25 wt.% to 50 wt.%, or at least any one of, equal to any one of, or between any two of 25, 30, 35, 40, 45 and 50 wt.% of naphthenes; ii) 10 wt.% to 35 wt.%, or at least any one of, equal to any one of, or between any two of 10, 15, 20, 25, 30 and 35 wt.% of aromatics; and iii) paraffins and isoparaffins with total concentration of 30 to 55 wt.% or at least any one of, equal to any one of, or between any two 30, 35, 40, 45, 50, and 55 wt.%, based on the total weight of the fourth stream respectively. In some aspects, the olefin content of the fourth stream 104 can be less than 8 wt.%, or less than 5 wt.%, or less than 3 wt.% or less than 1 wt.%, or the fourth stream 104 can be essentially free of olefins. In certain aspects, the composition of the stream B 511 can be similar to the fourth stream 104.

[0052] The third stream 103 and the stream A 510 can contain hydrocarbons having boiling points below 70 °C. The third stream 103 can contain paraffins and isoparaffins with total concentration of 90 to 100 wt.% or at least any one of, equal to any one of, or between

any two 90, 95, 96, 97, 98, 99, 99.3, 99.5, 99.8, 99.9 and 100 wt.%, based on the total weight of the third stream, respectively. In some aspects, the olefin content of the third stream 103 can be less than 8 wt.%, or less than 5 wt.%, or less than 3 wt.% or less than 1 wt.%, or the third stream can be essentially free of olefins. In some aspects, the aromatics content of the
5 third stream 103 can be less than 8 wt.%, or less than 5 wt.%, or less than 3 wt.% or less than 1 wt.%, or the third stream can be essentially free of aromatics. In certain aspects, the composition of the stream A 510 can be similar to the third stream 103.

[0053] The fifth stream 105 and the stream C 512 can contain hydrocarbons having boiling points above 140 °C.

10 **[0054]** In certain aspects, the ethylene, propylene and/or butylene from the light gas olefins streams, (127), can be purified/separated by one or more steps to obtain separated streams containing polymer grade ethylene, propylene and/or butylene.

[0055] In certain aspects, the benzene, toluene and xylene from the sixth stream 106, and/or the stream D 513 can be purified/separated by one or more steps to obtain separated
15 streams containing benzene, toluene and xylene.

[0056] Although embodiments of the present invention have been described with reference to blocks of FIG. 1-5, it should be appreciated that operation of the present invention is not limited to the particular blocks and/or the particular order of the blocks illustrated in FIG. 1-5. Accordingly, embodiments of the invention may provide functionality as described herein
20 using various blocks in a sequence different than that of FIG. 1-5.

[0057] The systems and processes described herein can also include various equipment that is not shown and is known to one of skill in the art of chemical processing. For example, some controllers, piping, computers, valves, pumps, heaters, thermocouples, pressure indicators, mixers, heat exchangers, and the like may not be shown.

25

EXAMPLE

[0058] As part of the disclosure of the present invention, specific examples are included below. The examples are for illustrative purposes only and are not intended to limit the invention. Those of ordinary skill in the art will readily recognize parameters that can be changed or modified to yield essentially the same results.

Example 1**Producing benzene, toluene and xylene and light gas olefins from a crude oil hydrocarbon fraction with upper boiling point cut of 350 °C**

[0059] A hydrocarbon fraction having an upper boiling point cut of 350 °C from crude oil was hydroprocessed at 380 °C, 60 barg, 1 h⁻¹ and H₂/hydrocarbon feed ratio 400 Nm³/m³ and in presence of a hydroprocessing catalyst (a combination of a hydrocracking catalyst Ni/W and a hydrotreating catalyst Co, Ni, Mo) to obtain a hydroprocessed stream. The hydroprocessed stream was distilled in an atmospheric column and was separated into a first hydrocarbon fraction, fraction 1, having upper boiling point cut of 70 °C, a second hydrocarbon fraction, fraction 2, having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C, and a third hydrocarbon fraction, fraction 3, having lower boiling point cut of 140 °C. Paraffins, isoparaffins, olefins, naphthenes and aromatics (PIONA) compositions of the hydrocarbon fractions 1, 2 and 3, based on the total weight of the hydroprocessed stream, are provided in Table 1. The hydrocarbon fraction 1 was steam cracked to obtain light gas olefins. The hydrocarbon fraction 2 was reformed in a naphtha reformer to obtain benzene, toluene and xylene. The hydrocarbon fraction 2 had more naphthenes, compared to two commonly used reformer feed (Table 2). Thus higher amounts of aromatics (e.g., benzene, toluene, and xylene) were produced from reforming hydrocarbon fraction 2, compared to the reforming feeds of Table 2. Further, as can be seen from table 1, hydrocarbon fraction 1 was completely paraffinic and was without aromatics and olefins, providing a good feed for the steam cracking/catalytic cracking.

Table 1. PIONA composition by hydroprocessing a hydrocarbon fraction with upper boiling point cut of 350 °C, obtained from crude oil.

Components	Hydrocarbon fraction 1	Hydrocarbon fraction 2	Hydrocarbon fraction 3
Normal Paraffin	6.8	4.6	3.3
Isoparaffin	30.8	10.9	2.6
Naphthenes	0	11.6	0.1
Branched Naphthenes	0	14.8	2.7
DiNaphthenes	0	0.1	0.4
Monoaromatics	0	7.8	3.4
Naphthenic aromatics	0	0	0.1
Diaromatics	0	0	0
Naphthenic diaromatics	0	0	0
Triaromatics	0	0	0
Total	37.6	49.8	12.6

Table 2: Typical PIONA composition of feed to the naphtha reformer.

Literature data	Turaga et al.	Mujtaba et al.
Paraffins	63	59
Naphthenes	23	20
Aromatics	14	21
Boiling range °C	85-160	88-180

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Example 2

Producing benzene, toluene and xylene and light gas olefins from a crude oil

[0060] West Texas blend crude oil with an end boiling point of 750 °C was hydroprocessed at 450 °C, 40 barg, 1 h⁻¹ and H₂/hydrocarbon feed ratio 400 Nm³/m³ and in presence of a hydroprocessing catalyst (a combination of a hydrocracking catalyst Ni/W and a hydrotreating catalyst Co, Ni, Mo) to obtain a hydroprocessed stream. The hydroprocessed stream was distilled in an atmospheric column and was separated into a first hydrocarbon fraction, fraction 4, having upper boiling point cut of 70 °C, a second hydrocarbon fraction, fraction 5, having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C, and a third hydrocarbon fraction, fraction 6, having lower boiling point cut of 140 °C. PIONA compositions of the hydrocarbon fractions 4 and 5, based on the total weight of the hydroprocessed stream, are provided in Table 3. The hydrocarbon fraction 4 was steam cracked to obtain light gas olefins. The hydrocarbon fraction 5 was reformed in a naphtha reformer to obtain benzene, toluene and xylene. 19.7 wt.% and 31 wt.% of the hydroprocessed stream was fractionated into the fractions 4 and 5, respectively, and the remaining amount was fractionated

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into the fraction 6. The hydrocarbon fraction 5 was primarily paraffinic and naphthenic, ~70 wt.% upon normalization, providing a good feed for reforming. Further, 31 wt.% of hydrocarbon fraction 5 was naphthenic, providing a good reforming feed for forming benzene, toluene and xylene. Olefin content of hydrocarbon fraction 4 was low, and was predominantly paraffinic, ~94.6% upon normalization, providing a good feed for steam cracking/catalytic cracking.

Table 3: PIONA composition obtained by hydroprocessing crude oil

Components	Hydrocarbon fraction 4	Hydrocarbon fraction 5
Normal Paraffin	8.3	4.6
Isoparaffin	10.3	7.3
Olefin	0.5	0.1
Naphthenes	0.5	9.8
Aromatics	0.0	9.3
Total	19.7	31

Example 3

10 Producing benzene, toluene and xylene and light gas olefins from Pyrolysis oil

[0061] A commercial pyrolysis oil having boiling point range 85 °C to 470 °C, was hydroprocessed at 400 °C, 60 barg, 1 h⁻¹ and H₂/hydrocarbon feed ratio 400 Nm³/m³ and in presence of a hydroprocessing catalyst (a combination of a hydrocracking catalyst Ni/W and a hydrotreating catalyst Co, Ni, Mo) to obtain a hydroprocessed stream. The hydroprocessed stream was distilled in an atmospheric column and was separated into a first hydrocarbon fraction, fraction 7, having upper boiling point cut of 70 °C, a second hydrocarbon fraction, fraction 8, having lower boiling point cut of 70 °C and upper boiling point cut of 140 °C, and a third hydrocarbon fraction, fraction 9, having lower boiling point cut of 140 °C. PIONA compositions of the hydrocarbon fractions 7, 8 and 9, based on the total weight of the hydroprocessed stream, are provided in Table 4. The hydrocarbon fraction 7 was steam cracked to obtain light gas olefins. The hydrocarbon fraction 8 was reformed in a naphtha reformer to obtain benzene, toluene and xylene. The hydrocarbon fraction 9 was recycled to the hydroprocessing step. 43.6 wt.%, 39 wt.% and 17.3 wt.% of the fraction 8 was paraffinic, naphthenic and aromatic respectively. Compared to typical reforming feed (Table 2), hydrocarbon fraction 8 had more naphthenes, thus was more suitable for producing benzene, toluene and xylene by reforming. Further, as can be seen from table 4, hydrocarbon fraction 7

was completely paraffinic and was without aromatics and olefins, providing a good feed for the steam cracker/catalytic cracking.

Table 4: PIONA composition by hydroprocessing pyrolysis oil

Components	Hydrocarbon fraction 7	Hydrocarbon fraction 8	Hydrocarbon fraction 9
Normal Paraffin	4.84	5.41	24.25
Isoparaffin	11.21	6.75	18.18
Naphthenes	0	4.17	1.07
Branched Naphthenes	0	6.67	6.86
DiNaphthenes	0	0.03	1.21
Monoaromatics	0	4.83	2.92
Naphthenic aromatics	0	0	1.33
Diaromatics	0	0	0.09
Naphthenic diaromatics	0	0	0
Triaromatics	0	0	0
Total	16.05	27.86	55.91

- 5 **[0062]** In the context of the present invention, at least the following 20 embodiments are described. Embodiment 1 is a process for selectively producing C₆ to C₈ aromatics and optionally light gas olefins. The process includes hydroprocessing a first stream containing hydrocarbons from crude oil and/or pyrolysis oil to obtain a second stream containing saturated hydrocarbons having boiling point less than 350 °C. The process further includes separating
- 10 the second stream to obtain a third stream containing hydrocarbons having boiling point less than 70 °C, a fourth stream containing hydrocarbons having boiling point 70 °C to 140 °C, and a fifth stream containing hydrocarbons having boiling point greater than 140 °C. The process still further includes recycling at least a portion of the fifth stream to the hydroprocessing step (a). The process also includes reforming the fourth stream to obtain a sixth stream containing
- 15 C₆ to C₈ aromatics. In addition, the process includes optionally cracking the third stream and/or a portion of the fifth stream to obtain light gas olefins. Embodiment 2 is the process of embodiment 1, wherein at least 70 wt.% of the second stream contains the saturated hydrocarbons having boiling point less than 350 °C. Embodiment 3 is the process of any of embodiments 1 or 2, wherein reforming step d) further includes obtaining a seventh stream
- 20 containing non-aromatics and non C₆ to C₈ aromatics and optionally recycling at least a portion of the seventh stream to the hydroprocessing step (a). Embodiment 4 is the process of any of embodiments 1 to 3, wherein the hydroprocessing conditions in step (a) include a pressure

lower than 100 barg, preferably 30 barg to 100 barg, a temperature 300 °C to 600 °C, weight hourly space velocity 0.5 to 2 hr⁻¹, or H₂ : hydrocarbon volume ratio of 200 Nm³:1 m³ to 2000 Nm³:1 m³ of liquid feed, or any combinations or all thereof. Embodiment 5 is the process of any of embodiments 1 to 4, wherein the hydroprocessing in step (a) is performed using a dissolved catalyst containing Ni and/or Mo, and a fixed bed catalyst containing Co, Mo, Ni, W, or any combinations thereof on a support. Embodiment 6 is the process of any of embodiments 1 to 5, wherein the reforming conditions in step (b) include a temperature of 450 °C to 550 °C, a pressure of 2 barg to 30 barg, or H₂ : hydrocarbon mole ratio of 2:1 to 9:1, or any combinations or all thereof. Embodiment 7 is the process of any of embodiments 1 to 6, wherein the reforming in step (d) is performed using a reforming catalyst containing Pt-Re on alumina, Pt on alumina, metal loaded zeolite, or a combinations thereof. Embodiment 8 is the process of any of embodiments 1 to 7, wherein the pyrolysis oil is obtained from plastic. Embodiment 9 is the process of any of embodiments 1 to 8, wherein the pyrolysis oil is obtained from the plastic by depolymerizing the plastic at a depolymerization temperature sufficient to produce a hydrocarbonaceous wax stream, and cracking the hydrocarbonaceous wax stream in the presence of a cracking catalyst under cracking conditions sufficient to produce the pyrolysis oil, wherein the cracking conditions include a cracking temperature that is higher than, or equal to, or lower than the depolymerization temperature. Embodiment 10 is the process of any of embodiments 1 to 9, wherein the first stream contains hydrocarbons having boiling point above 140 °C separated from the crude oil and/or the pyrolysis oil by atmospheric distillation. Embodiment 11 is the process of any of embodiments 1 to 10, wherein the atmospheric distillation further produces a eighth stream containing hydrocarbons having boiling points of 70 °C to 140 °C, and the process further includes reforming the eighth stream. Embodiment 12 is the process of any of embodiments 1 to 11, wherein eighth stream is reformed with the fourth stream to form the sixth stream and the seventh stream. Embodiment 13 is the process of any of embodiments 1 to 12, wherein the atmospheric distillation further produces a ninth stream containing hydrocarbons having boiling point below 70 °C. Embodiment 14 is the process of any of embodiments 1 to 3, wherein the ninth stream is cracked with the third stream to produce the light gas olefins or is sent to the hydroprocessing step. Embodiment 15 is the process of any of embodiments 1 to 14, wherein the first stream contains pyrolysis oil. Embodiment 16 is the process of any of embodiments 1 to 15, wherein the first stream contains condensate, naphtha, light crude oil, or a crude oil hydrocarbon fraction having an upper boiling point cut of 350 °C or whole crude oil, or any combinations or all thereof.

[0063] Embodiment 17 is a process for selectively producing C₆ to C₈ aromatics and optionally light gas olefins from plastics. The process includes: a) performing reactive extrusion or melt cracking of plastics to form pyrolysis oil; b) separating the pyrolysis oil to obtain a stream A containing hydrocarbons having boiling point less than 70 °C, a stream B
5 containing hydrocarbons having boiling point 70 °C to 140 °C, and a stream C containing hydrocarbons having boiling point greater than 140 °C; c) reforming the stream B to obtain a stream D containing C₆ to C₈ aromatics; and d) optionally mixing the stream A to a gasoline pool of a refinery. Embodiment 18 is the process of embodiment 17, wherein the reactive extrusion or melt cracking of plastics includes depolymerizing of the plastic at a
10 depolymerization temperature sufficient to produce a hydrocarbonaceous wax stream; and catalytic cracking the hydrocarbonaceous wax stream in presence of a cracking catalyst under cracking conditions sufficient to produce the pyrolysis oil, wherein the cracking conditions include a cracking temperature that is higher than, or equal to, or lower than the depolymerization temperature. Embodiment 19 is the process of any of embodiments 17 to 18,
15 further including recycling the stream C to the catalytic cracking step. Embodiment 20 is the process of any of embodiments 17 to 19, wherein at least a portion of hydrogen containing gases, non-aromatics, and non C₆ to C₈ aromatics obtained from reforming in step (c) is recycled to the catalytic cracking step.

[0064] All embodiments described above and herein can be combined in any manner
20 unless expressly excluded.

[0065] Although embodiments of the present application and their advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the embodiments as defined by the appended claims. Moreover, the scope of the present application is not
25 intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the above disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same
30 result as the corresponding embodiments described herein may be utilized. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

CLAIMS

1. A process for selectively producing C₆ to C₈ aromatics and optionally light gas olefins, the process comprising:
 - a) hydroprocessing a first stream comprising hydrocarbons from crude oil and/or pyrolysis oil to obtain a second stream comprising saturated hydrocarbons having boiling point less than 350 °C;
 - b) separating the second stream to obtain a third stream comprising hydrocarbons having boiling point less than 70 °C, a fourth stream comprising hydrocarbons having boiling point 70 °C to 140 °C, and a fifth stream comprising hydrocarbons having boiling point greater than 140 °C;
 - c) recycling at least a portion of the fifth stream to the hydroprocessing step (a);
 - d) reforming the fourth stream to obtain a sixth stream comprising C₆ to C₈ aromatics; and
 - e) optionally cracking the third stream and/or a portion of the fifth stream to obtain light gas olefins.
2. The process of claim 1, wherein at least 70 wt.% of the second stream is comprised of the saturated hydrocarbons having boiling point less than 350 °C.
3. The process of claims 1 or 2, wherein reforming step d) further comprises obtaining a seventh stream comprising non-aromatics and non C₆ to C₈ aromatics and optionally recycling at least a portion of the seventh stream to the hydroprocessing step (a).
4. The process of any one of claims 1 to 2, wherein the hydroprocessing conditions in step (a) comprise a pressure lower than 100 barg, preferably 30 barg to 100 barg, a temperature 300 °C to 600 °C, weight hourly space velocity 0.5 to 2 hr⁻¹, or H₂ : hydrocarbon volume ratio of 200 Nm³:1 m³ to 2000 Nm³:1 m³ of liquid feed, or any combinations or all thereof.
5. The process of claim 4, wherein the hydroprocessing in step (a) is performed using a dissolved catalyst comprising Ni and/or Mo, and a fixed bed catalyst comprising Co, Mo, Ni, W, or any combinations thereof on a support.

6. The process of any one of claims 1 to 2, wherein the reforming conditions in step (b) comprise a temperature of 450 °C to 550 °C, a pressure of 2 barg to 30 barg, or H₂ : hydrocarbon mole ratio of 2:1 to 9:1, or any combinations or all thereof.
7. The process of any one of claims 1 to 2, wherein the reforming in step (d) is performed using a reforming catalyst comprising Pt-Re on alumina, Pt on alumina, metal loaded zeolite, or a combinations thereof.
8. The process of any one of claims 1 to 2, wherein the pyrolysis oil is obtained from plastic.
9. The process of claim 8, wherein the pyrolysis oil is obtained from the plastic by depolymerizing the plastic at a depolymerization temperature sufficient to produce a hydrocarbonaceous wax stream; and cracking the hydrocarbonaceous wax stream in the presence of a cracking catalyst under cracking conditions sufficient to produce the pyrolysis oil, wherein the cracking conditions include a cracking temperature that is higher than, or equal to, or lower than the depolymerization temperature.
10. The process of any one of claims 1 to 2, wherein the first stream comprises hydrocarbons having boiling point above 140 °C separated from the crude oil and/or the pyrolysis oil by atmospheric distillation.
11. The process of claim 10, wherein the atmospheric distillation further produces a eighth stream comprising hydrocarbons having boiling points of 70 °C to 140 °C, and the process further comprises reforming the eighth stream.
12. The process of claim 10, wherein eight stream is reformed with the fourth stream to form the sixth stream and the seventh stream.
13. The process of claim 10, wherein the atmospheric distillation further produces a ninth stream comprising hydrocarbons having boiling point below 70 °C.
14. The process of claim 13, wherein the ninth stream is cracked with the third stream to produce the light gas olefins or is sent to the hydroprocessing step.
15. The process of any one of claims 1 to 2, wherein the first stream comprises pyrolysis oil.
16. The process of any one of claims 1 to 2, wherein the first stream comprises condensate, naphtha, light crude oil, or a crude oil hydrocarbon fraction having an upper boiling point cut of 350 °C or whole crude oil, or any combinations or all thereof.

17. A process for selectively producing C₆ to C₈ aromatics and optionally light gas olefins from plastics, the process comprising:
 - a) performing reactive extrusion or melt cracking of plastics to form pyrolysis oil;
 - b) separating the pyrolysis oil to obtain a stream A comprising hydrocarbons having boiling point less than 70 °C, a stream B comprising hydrocarbons having boiling point 70 °C to 140 °C, and a stream C comprising hydrocarbons having boiling point greater than 140 °C;
 - c) reforming the stream B to obtain a stream D comprising C₆ to C₈ aromatics; and
 - d) optionally mixing the stream A to a gasoline pool of a refinery.
18. The process of claim 17, wherein the reactive extrusion or melt cracking of plastics comprises, depolymerizing of the plastic at a depolymerization temperature sufficient to produce a hydrocarbonaceous wax stream; and catalytic cracking the hydrocarbonaceous wax stream in presence of a cracking catalyst under cracking conditions sufficient to produce the pyrolysis oil, wherein the cracking conditions include a cracking temperature that is higher than, or equal to, or lower than the depolymerization temperature.
19. The process of claim 18, further comprising recycling the stream C to the catalytic cracking step.
20. The process of any one of claims 18 to 19, wherein at least a portion of hydrogen containing gases, non-aromatics, and non C₆ to C₈ aromatics obtained from reforming in step (c) is recycled to the catalytic cracking step.