Title: Process and plant for producing hydrocarbons with reduced CO_2-footprint and improved hydrogen integration

FIELD OF THE INVENTION

The present invention relates to a hydrotreatment process and plant for producing a hydrocarbon product boiling in transportation fuel range, in particular any of the diesel fuel boiling range, jet fuel boiling range and naphtha boiling range, by the hydroprocessing of a feedstock originating from renewable sources, and which is combined i.e. integrated with a hydrogen producing unit for generating at least part of the hydrogen required in said hydroprocessing, thereby drastically reducing hydrocarbon consumption, particularly natural gas used as feed and fuel in the hydrogen producing unit, whilst also minimizing carbon dioxide footprint and plant costs.

BACKGROUND OF THE INVENTION

There is a growing interest to produce diesel, jet fuel and naphtha from renewable feedstocks. Often this renewable feedstock contains high amount of oxygen compound and unsaturated hydrocarbon. During the hydrotreating of renewable feedstock, the oxygen is mainly removed as H_2O, which gives a paraffinic fuel consisting of paraffins with the same number for carbon atoms as in the backbone of the triglycerides. This is called the hydrodeoxygenation (HDO) pathway. Oxygen can also be removed by dicarboxylic pathway, which generates CO_2 instead of H_2O.

HDO pathway: $C_{17}H_{34}COOH + 3.5\ H_2 \leftrightarrow C_{18}H_{38} + 2\ H_2O$

Decarboxylation pathway: $C_{17}H_{34}COOH + 0.5\ H_2 \leftrightarrow C_{17}H_{36} + CO_2$

Besides, there are some side reactions

Gas-water shift reaction: $CO_2 + H_2 \leftrightarrow CO + H_2O$

Methanation: $CO + 3\ H_2 \leftrightarrow CH_4 + H_2O$

Some of the renewable feed also contain nitrogen. Removing nitrogen also requires hydrogen.

separator is conducted to a product recovery section, whereby a CO_2-rich fraction is withdrawn. A portion of lighter materials (LPG analogue) from downstream fractionation is optionally conducted to a hydrogen generation unit, thereby producing hydrogen which is used in the process, optionally together with an external source of make-up hydrogen.

SUMMARY ~~OF THE INVENTION~~

We have found that apart from the reduction of the total consumption of hydrogen, it is now also possible to integrate a renewable feed hydrotreatment unit with a hydrogen production unit and minimize the energy consumption for the overall process/plant, mainly by minimizing natural gas consumption for production of hydrogen required for hydro-processing of the renewable feed, thereby drastically reducing the carbon dioxide footprint of the plant.

In a first aspect of the present disclosure, there is provided a process for producing a hydrocarbon product, said process comprising the steps of:

i) passing a feedstock originating from a renewable source through a hydroprocessing stage for producing a main hydrotrotreated stream;

ii) passing the main hydrotreated stream to a separation stage for producing:

an aqueous stream,

a hydrogen-rich stream as a first recycle gas stream,

an off-gas stream comprising hydrocarbons,

and said hydrocarbon product, boiling at above 50°C;

iii) passing the first recycle gas stream to the hydroprocessing stage;

iv) passing the off-gas stream as a second recycle gas stream to a hydrogen producing unit for producing a hydrogen stream as a make-up hydrogen stream;

v) passing the make-up hydrogen stream to the hydroprocessing stage;

wherein prior to conducting step iv), said off-gas stream passes to a separation stage, the separation stage preferably being at least one of an amine absorption stage, a caustic scrubber, and a sulfur absorbent, for removing H_2S and thereby producing said second recycle gas stream.

In a second aspect of the present disclosure, there is provided a plant for producing a hydrocarbon product, comprising:

- a hydroprocessing section arranged to receive a feedstock originating from a renewable source and a compressed hydrogen-rich feed stream for producing a main hydrotreated stream;
- a separation section arranged to receive said main hydrotreated stream for producing an aqueous stream, a hydrogen-rich stream as a first recycle gas stream, an off-gas stream comprising hydrocarbons as a second recycle stream, and said hydrocarbon product, boiling at above 50°C;
- a separation section, which is preferably at least one of an amine absorption stage, a caustic scrubber, and a sulfur absorbent, arranged to receive said off-gas stream, for removing H_2S and thereby producing said second recycle gas stream;
- a hydrogen producing unit (HPU) arranged to receive said second recycle gas stream and a hydrocarbon feedstock for producing a make-up hydrogen stream;
- a compressor section arranged to receive said first recycle gas stream and at least a portion of the make-up hydrogen stream produced in said HPU, for generating said compressed hydrogen-rich feed stream and a make-up hydrogen recycle stream;
- a conduit for passing said first recycle gas stream to said compressor section;
- a conduit for passing said make-up hydrogen stream from the HPU to said compressor section;
- optionally a conduit for recycling said make-up hydrogen recycle stream to the HPU.
- optionally means for splitting said hydrogen-rich stream into said first recycle gas stream and a third recycle gas stream, and a conduit for passing said third recycle gas stream to said HPU.

Accordingly, in a first ~~aspect~~example, the ~~invention~~present disclosure provides a process for producing a hydrocarbon product, said process comprising the steps of:

i) passing a feedstock originating from a renewable source through a hydroprocessing stage for producing a main hydrotrotreated stream;

ii) passing the main hydrotreated stream to a separation stage for producing:

an aqueous stream;

a hydrogen-rich stream as a first recycle gas stream;

an off-gas stream comprising hydrocarbons;

and said hydrocarbon product, boiling at above 50°C;

iii) passing the first recycle gas stream to the hydroprocessing stage;

iv) passing the second recycle gas stream to a hydrogen producing unit for producing a hydrogen stream as a make-up hydrogen stream;

v) passing the make-up hydrogen stream to the hydroprocessing stage;

wherein prior to conducting step iv), said off-gas stream passes to a separation stage, the separation stage preferably being at least one of an amine absorption stage, a caustic scrubber, and a sulfur absorbent, for removing H_2S and thereby producing said second recycle gas stream.

It would be understood, that for the purposes of the present application, the hydrogen rich stream is also referred as first recycle gas stream. The off-gas stream comprising hydrocarbons, is also simply referred as off-gas stream.

The obtained second recycle gas stream entering the hydrogen producing unit contains therefore light hydrocarbons such as C1-C4 hydrocarbons, H_2, NH_3, CO and CO_2, yet no H_2S or only minor amounts of H_2S. The off-gas stream and second recycle stream derived thereof contains hydrogen not consumed from the hydrotreating unit(s) of the hydroprocessing stage as soluble hydrogen in hydrocarbon phase, and is suitably used as part of the feed in the hydrogen producing unit, which is described farther below.

Hence, a hydroprocessing and separation stage for producing renewable hydrocarbon products is integrated with a hydrogen producing unit in an overall process or plant by use of at least two recycle streams separately withdrawn from the separation stage, thereby drastically reducing energy consumption figures, in particular natural gas used as feed and fuel in the process, as it will become apparent from the description and examples farther below. For instance, by the ~~invention~~present disclosure a significant reduction in natural gas consumption in the range 40-90% or more is achieved in the hydrogen producing unit, whilst at the same time enabling a smaller size of the hydrogen production unit.

In an ~~embodiment~~example, the entire off-gas stream passes to the separation stage. Hence, there is full utilization within the process and plant of such off-gas stream and thereby integration.

In an ~~embodiment~~example, the entire second recycle gas stream passes to the hydrogen producing unit. Thereby there is less consumption of e.g. the natural gas used as feed and fuel in the hydrogen producing unit, compared to an instance where only a portion of the second recycle stream is passed to the hydrogen producing unit.

In an ~~embodiment~~example, said hydrogen-rich stream comprises 50% vol. H_2 or more, light hydrocarbons such as C1-C4 hydrocarbons, optionally also H_2S and NH_3, CO and CO_2.

By the ~~invention~~present disclosure, said hydrogen-rich stream, i.e. the first recycle gas stream, is not subjected to a separation stage for removing H_2S and/or CO_2, optionally also for removing

NH_3 and/or CO, prior to being passed to the hydroprocessing stage, in particular prior to being passed to the first catalytic hydrotreating unit therein. The first catalytic hydrotreating unit is suitably for hydrodeoxygenation, as it will become apparent from the description farther below.

The first recycle gas stream is significantly larger i.e. significantly larger flow rate, than the off-gas stream, thus the provision of a separation stage such as an amine scrubber in the first recycle stream for removing H_2S and/or CO_2, often for removing H_2S and CO_2, is by the present ~~invention~~disclosure obviated, without incurring any penalty in the process, for instance by using a nickel-molybdenum catalyst for hydrodeoxygenation as in applicant's co-pending patent application EP 20162755.1. Furthermore, renewable feeds such as vegetable oil, animal fat etc., often lack enough sulfur compared with conventional fossil feed. As a result, an external sulfur agent such as dimethyl disulfide (DMDS) or other sulfur agent has normally been introduced with conventional fossil feed to provide the minimum required H_2S amount in the hydrogen rich gas to hydrodeoxygenation to keep the hydrotreating e.g. hydrodeoxygenation catalyst therein in sulfided form. So, use of high pressure amine absorber will remove the H_2S from recycle gas prior to sending back to the hydroprocessing. This results in more addition of external sulfur agent and added cost.

By the ~~invention~~present disclosure, a separation stage such as an amine scrubber is provided in the much smaller off-gas stream and targeted for H_2S removal, thereby simplifying the process and reducing capital and operating expenses, as well as reducing energy consumption, by virtue of using a smaller separation stage in a smaller stream, i.e. the off-gas stream. More specifically, there is less amine, e.g. lean amine, requirement thus resulting in a smaller amine regeneration unit and less amount of steam required to regenerate the amine. In addition, the amine scrubber in the off-gas stream is suitably a low pressure amine absorption system, which conveys much lower capital and operating expenses compared to high pressure amine absorption systems which are normally used when cleaning the first recycle gas prior to passing it to the hydrodeoxygenation.

Furthermore, while it is also possible to remove the CO_2 in the off-gas stream, suitably the CO_2 is not removed for avoiding the emission of CO_2 to the atmosphere, since the hydrogen producing unit, e.g. a pre-reforming unit therein, can operate with the second

recycle also containing CO_2. A lower carbon footprint is thereby obtained. Where necessary, an amine which is more selective towards H_2S removal can be selected, with CO_2 removal being incidental. The removal of H_2S from the off-gas stream minimizes the need for sulfur adsorbent in the hydrogen producing unit, in particular a cleaning unit therein.

In an ~~embodiment~~example, said off-gas stream comprises light hydrocarbons in the form of C1-C4 hydrocarbons, H_2, CO, CO_2, and optionally also H_2S.

In an ~~embodiment~~example, said hydrocarbon product, boiling at above 50°C, is a hydrocarbon product boiling at least in one of: the diesel fuel boiling range, jet fuel boiling range, and naphtha boiling range.

In an ~~embodiment~~example, the process further comprises: vi) splitting said hydrogen-rich stream into said first recycle gas stream and a third recycle gas stream, and passing said third recycle gas stream to said hydrogen producing unit. Thereby, further integration is achieved. The third recycle gas stream is withdrawn as a purge stream which by passing it to the hydrogen producing unit enables increasing the purity of the hydrogen loop.

In an ~~embodiment~~example, in step i) the hydroprocessing stage comprises:
i-1) passing the feedstock through a first catalytic hydrotreating unit under the addition of hydrogen for producing a first hydrotreated stream, preferably comprising C1-C30 hydrocarbons;
i-2) passing the first hydrotreated stream to a dewaxing section comprising a second catalytic hydrotreating unit under the addition of hydrogen for producing said main hydrotreated stream.

In an ~~embodiment~~example, said first hydrotreated stream comprises C1-C30 hydrocarbons.

Optionally, the process comprises using one or more additional catalytic hydrotreating units under the addition of hydrogen, such as third catalytic hydrotreating unit or a cracking section. For instance, it would be understood that when a hydrocarbon product boiling in the jet fuel range is desired, a hydrocracking unit is suitably used, for

instance prior to passing the thus resulting first hydrotreated stream to the dewaxing section.

In a particular ~~embodiment~~example, between step i-1) and i-2) the process further comprises passing the first hydrotreated stream to a separator such as a high-pressure or low-pressure separator, for removing H_2S, NH_3, and H_2O, thereby producing said first hydrotreated stream, and optionally also producing a vapor stream, and a recycle oil stream.

The first hydrotreated stream from the first catalytic hydrotreating unit normally contains impurities, in particular H_2S, NH_3, CO and CO_2 which may be detrimental for the catalyst used in the subsequent dewaxing section. When the process is operated in so-called sour mode, the catalyst of the dewaxing section is a base-metal catalyst, which is resistant to impurities, thereby avoiding the need of using a separator. When operating in the so-called sweet mode, the catalyst of the dewaxing section is a noble-metal catalyst, which is sensitive to the impurities, thereby requiring the need of using the separator.

In an ~~embodiment~~example, in step ii) the separation stage comprises:
ii-1) passing the main hydrotreated stream to a separator, preferably a cold separator, for producing said aqueous stream, said hydrogen-rich stream, and a heavy hydrocarbon stream;
ii-2) passing the heavy hydrocarbon stream to a fractionation section, such as stripping section, for producing said off-gas stream, and said hydrocarbon product e.g. a hydrocarbon product boiling at least in one of: the diesel fuel boiling range, jet fuel boiling range, and naphtha boiling range.

In an ~~embodiment~~example, said heavy hydrocarbon stream comprises C5-C30 hydrocarbons, H_2, CO and CO_2.

In an ~~embodiment~~example, in step v) the make-up hydrogen stream passes to at least one of:
said first catalytic hydrotreating unit;
said separator between step i-1) and i-2), such as a high pressure stripper;
second catalytic hydrotreating unit;

and optionally also an additional catalytic hydrotreating unit such as a third catalytic hydrotreating unit.

In an ~~embodiment~~example, the first recycle stream is passed to the first catalytic hydrotreating unit.

It would be understood, that the addition of hydrogen of step i), in particular step i-1), i-2) and optionally also in the step in between, i.e. passing the first hydrotreated stream to a separator for removing H_2S and NH_3, is mainly from said make-up hydrogen stream and said first recycle stream. The present ~~invention~~disclosure provides a high level of integration, hence there is no need to resort to the use of external make-up hydrogen, i.e. make-up hydrogen supplied from outside the process and plant of the present ~~invention~~present disclosure.

In an ~~embodiment~~example, the hydrogen producing unit comprises feeding: said second recycle gas stream, and a hydrocarbon feedstock such as natural gas, optionally together with one or more of said hydrocarbon products, such as naphtha and other light products, i.e. “renewable naphtha” produced in the process. Natural gas and optionally said naphtha, and the second recycle stream are preferably fed separately to the hydrogen producing unit. It is also envisaged, that the thus recycled naphtha and other light products is used as the major portion of or even all of the hydrocarbon feedstock. By including a part of the hydrocarbon product, in particular the renewable naphtha as part of the hydrocarbon feed to the hydrogen producing unit, an even higher reduction in energy consumption is achieved.

The hydrocarbon feedstock for the hydrogen production unit may also include LPG, biogas, methane, or combinations thereof.

It would also be understood that said hydrocarbon products, i.e. products produced according to the process of the ~~invention~~present disclosure represent so-called green products or renewable products, thus the diesel product is a renewable diesel, the jet fuel is a renewable jet fuel and the naphtha is a renewable naphtha.

In an ~~embodiment~~example, the hydrogen producing unit comprises subjecting the hydrocarbon feedstock to: cleaning in a cleaning unit, said cleaning unit preferably being a sulfur-chlorine-metal absorption or catalytic unit; optionally pre-reforming in a pre-reforming unit; catalytic steam methane reforming in a steam reforming unit; water gas shift conversion in a water gas shift unit; optionally carbon dioxide removal in a CO_2-separator unit; and hydrogen purification in a hydrogen purification unit.

In a particular ~~embodiment~~example, said second recycle gas stream is fed to the cleaning unit. This is an efficient way of utilizing available hydrogen in the process, as the sulfur-chlorine-metal absorption or catalytic unit normally requires addition of hydrogen.

In an ~~embodiment~~example, the hydrogen-rich stream, or first recycle stream, or third recycle stream comprises hydrogen in a concentration of 50 vol% or higher, preferably 70% vol. hydrogen or higher, and any of said streams is passed through a hydrogen purification unit: prior to splitting said hydrogen-rich stream into a first recycle stream or a third recycle stream, or prior to passing the first recycle stream to the hydroprocessing stage, or prior to passing said third recycle stream to hydrogen producing unit. Preferably, only the third recycle stream passes to the hydrogen purification unit.

This enables that the steam reformer size be reduced, thereby minimizing the overall capital expenses of the hydrogen production unit.

The hydrogen purification unit may be a H_2-membrane unit, or a Pressure Swing Adsorption unit (PSA-unit).

While the above hydrogen purification unit may be a dedicated (separate) unit, in a particular ~~embodiment~~example the hydrogen purification unit is the hydrogen purification unit of the hydrogen producing unit, and said third recycle stream is passed through this hydrogen purification unit. This further facilitates integration and higher energy efficiency of the overall plant/process, i.e. section comprising hydroprocessing and separation stages, and the hydrogen producing unit. In addition, there is a more expedient use of the already available hydrogen purification unit of the hydrogen producing unit, since one normally would expect a requirement of this unit to provide a hydrogen stream with at least 99 vol.% H_2, whereas by the present ~~invention~~disclosure there is a less strict requirement on

hydrogen purity, as this hydrogen is used in the hydroprocessing stage, in particular the first, second catalytic hydrotreatment, as well as any additional catalytic hydrotreatment, such as a third catalytic hydrotreatment.

In another particular ~~embodiment~~example, the hydrogen purification unit is a Pressure Swing Adsorption unit (PSA unit), said PSA unit producing an off-gas stream, i.e. PSA off-gas,which is used as fuel in the steam reforming unit of the hydrogen producing unit, and/or in fired heaters in any of the catalytic hydrotreating units of the hydroprocessing stage, separation units of the separation stage, and/or for steam production. This enables further reduction of hydrocarbon consumption, thereby improving energy consumption figures, i.e. higher energy efficiency, as PSA off-gas which otherwise will need to be burned off (flared), is expediently used in the process.

In an ~~embodiment~~example, the steam reforming unit is: a convection reformer, preferably comprising one or more bayonet reforming tubes such as an HTCR reformer i.e. Topsøe bayonet reformer, where the heat for reforming is transferred by convection along with radiation; a tubular reformer i.e. conventional steam methane reformer (SMR), where the heat for reforming is transferred chiefly by radiation in a radiant furnace; autothermal reformer (ATR), where partial oxidation of the hydrocarbon feed with oxygen and steam followed by catalytic reforming; electrically heated steam methane reformer (e-SMR), where electrical resistance is used for generating the heat for catalytic reforming; or combinations thereof. In particular, when using e-SMR, electricity from green resources may be utilized, such as from electricity produced by wind power, hydropower, and solar sources, thereby further minimizing the carbon dioxide footprint.

For more information on these reformers, details are herein provided by direct reference to Applicant's patents and/or literature. For instance, for tubular and autothermal reforming an overview is presented in "Tubular reforming and autothermal reforming of natural gas – an overview of available processes", Ib Dybkjær, Fuel Processing Technology 42 (1995) 85-107; and EP 0535505 for a description of HTCR. For a description of ATR and/or SMR for large scale hydrogen production, see e.g. the article "Large-scale Hydrogen Production", Jens R. Rostrup-Nielsen and Thomas Rostrup-Nielsen": https://www.topsoe.com/sites/default/files/topsoe_large_scale_hydrogen_produc.pdf

For a description of e-SMR which is a more recent technology, reference is given to in particular WO 2019/228797 A1.

In an ~~embodiment~~example, the catalyst in the steam reforming unit is a reforming catalyst, e.g. a nickel based catalyst. In an ~~embodiment~~example, the catalyst in the water gas shift reaction is any catalyst active for water gas shift reactions. The said two catalysts can be identical or different. Examples of reforming catalysts are $Ni/MgAl_2O_4$, Ni/Al_2O_3, $Ni/CaAl_2O_4$, $Ru/MgAl_2O_4$, $Rh/MgAl_2O_4$, $Ir/MgAl_2O_4$, Mo_2C, Wo_2C, CeO_2, Ni/ZrO_2, $Ni/MgAl_2O_3$, $Ni/CaAl_2O_3$, $Ru/MgAl_2O_3$, or $Rh/MgAl_2O_3$, a noble metal on an Al_2O_3 carrier, but other catalysts suitable for reforming are also conceivable. The catalytically active material may be Ni, Ru, Rh, Ir, or a combination thereof, while the ceramic coating may be Al_2O_3, ZrO_2, $MgAl_2O_3$, $CaAl_2O_3$, or a combination therefore and potentially mixed with oxides of Y, Ti, La, or Ce. The maximum temperature of the reactor may be between 850-1300°C. The pressure of the feed gas may be 15-180 bar, preferably about 25 bar. Steam reforming catalyst is also denoted steam methane reforming catalyst or methane reforming catalyst.

In an ~~embodiment~~example, prior to passing the make-up hydrogen stream to the hydroprocessing stage, the makeup hydrogen stream passes through a compressor section comprising a make-up compressor optionally also a recycle compressor, the make-up compressor also producing a hydrogen recycle stream which is added to the hydrogen producing unit, preferably directly to the second recycle stream entering the hydrogen producing unit, and/or to the cleaning unit of the hydrogen producing unit. This enables even better integration, since there is no need for a separate or dedicated compressor for recycling hydrogen within the hydrogen producing unit for e.g. hydrogenation of sulfur in the cleaning unit.

In a particular ~~embodiment~~example, prior to passing the first recycle stream to the hydroprocessing stage, the first recycle stream passes through said recycle compressor, i.e. recycle compressor comprised in the compressor section.

In an ~~embodiment~~example, the feedstock is obtained from a raw material of renewable origin, such as originating from plants, algae, animals, fish, vegetable oil refining, domestic waste, waste rich in plastic, industrial organic waste like tall oil or black liquor, or a

feedstock derived from one or more oxygenates taken from the group consisting of triglycerides, fatty acids, resin acids, ketones, aldehydes or alcohols where said oxygenates originate from one or more of a biological source, a gasification process, a pyrolysis process, Fischer-Tropsch synthesis, or methanol based synthesis. The oxygenates may also originate from a further synthesis process. Some of these feedstocks may contain aromatics; especially products from pyrolysis processes or waste products from e.g. frying oil. Any combinations of the above feedstocks are also envisaged.

In another ~~embodiment~~example, step i) may also comprise adding a feedstock originating from a fossil fuel source, such as diesel, kerosene, naphtha, and vacuum gas oil (VGO), or a recycled hydrocarbon product. This additional feedstock acts as a hydrocarbon diluent, thereby enabling the absorption of heat from the exothermal reactions in the catalytic hydrotreating unit(s) of the hydroprocessing stage.

In an ~~embodiment~~example, the first catalytic hydrotreating unit is hydrodeoxygenation (HDO) i.e. HDO is conducted in a HDO unit, the second catalytic hydrotreating is hydrodewaxing (HDW), and an additional catalytic hydrotreating such as a third catalytic hydrotreating is hydrocracking (HCR).

The material catalytically active in hydrotreating, typically comprises an active metal (sulfided base metals such as nickel, cobalt, tungsten and/or molybdenum, but possibly also either elemental noble metals such as platinum and/or palladium) and a refractory support (such as alumina, silica or titania, or combinations thereof).

Hydrotreating conditions involve a temperature in the interval 250-400°C, a pressure in the interval 30-150 bar, and a liquid hourly space velocity (LHSV) in the interval 0.1-2, optionally together with intermediate cooling by quenching with cold hydrogen, feed or product

The material catalytically active in hydrodewaxing typically comprises an active metal (either elemental noble metals such as platinum and/or palladium or sulfided base metals such as nickel, cobalt, tungsten and/or molybdenum), an acidic support (typically a molecular sieve showing high shape selectivity, and having a topology such as MOR,

FER, MRE, MWW, AEL, TON and MTT) and a refractory support (such as alumina, silica or titania, or combinations thereof).

Isomerization conditions involve a temperature in the interval 250-400°C, a pressure in the interval 20-100 bar, and a liquid hourly space velocity (LHSV) in the interval 0.5-8.

The material catalytically active in hydrocracking is of similar nature to the material catalytically active in isomerization, and it typically comprises an active metal (either elemental noble metals such as platinum and/or palladium or sulfided base metals such as nickel, cobalt, tungsten and/or molybdenum), an acidic support (typically a molecular sieve showing high cracking activity, and having a topology such as MFI, BEA and FAU) and a refractory support (such as alumina, silica or titania, or combinations thereof). The difference to material catalytically active isomerization is typically the nature of the acidic support, which may be of a different structure (even amorphous silica-alumina) or have a different acidity e.g. due to silica:alumina ratio.

Hydrocracking conditions involve a temperature in the interval 250-400°C, a pressure in the interval 30-150 bar, and a liquid hourly space velocity (LHSV) in the interval 0.5-8, optionally together with intermediate cooling by quenching with cold hydrogen, feed or product

Other types of hydrotreating are also envisaged, for instance hydrodearomatization (HDA). The material catalytically active in hydrodearomatization typically comprises an active metal (typically elemental noble metals such as platinum and/or palladium but possibly also sulfided base metals such as nickel, cobalt, tungsten and/or molybdenum) and a refractory support (such as amorphous silica-alumina, alumina, silica or titania, or combinations thereof).

Hydrodearomatization conditions involve a temperature in the interval 200 -350°C, a pressure in the interval 20-100 bar, and a liquid hourly space velocity (LHSV) in the interval 0.5-8.

In second ~~aspect~~example, the ~~invention~~present disclosure encompasses also the treatment of a feedstock originating from a fossil fuel source.

Accordingly, there is also provided a process for producing a hydrocarbon product, said process comprising the steps of:

i) passing a feedstock originating from a fossil fuel source through a hydroprocessing stage for producing a main hydrotrotreated stream;

ii) passing the main hydrotreated stream to a separation stage for producing:

optionally an aqueous stream,

a hydrogen-rich stream as a first recycle gas stream,

an off-gas stream comprising hydrocarbons,

and said hydrocarbon product, boiling at above 50°C;

iii) passing the first recycle gas stream to the hydroprocessing stage;

iv) passing the off-gas stream as a second recycle gas stream to a hydrogen producing unit for producing a hydrogen stream as a make-up hydrogen stream;

v) passing the make-up hydrogen stream to the hydroprocessing stage;

wherein prior to conducting step iv), said off-gas stream passes to a separation stage, the separation stage preferably being at least one of an amine absorption stage, a caustic scrubber, and a sulfur absorbent, for removing H_2S and thereby producing said second recycle gas stream.

In an ~~embodiment~~example of the second ~~aspect~~example of the ~~invention~~present disclosure, the feedstock originating from a fossil fuel is diesel, kerosene, naphtha, and vacuum gas oil (VGO).

In another ~~embodiment~~example of the second ~~aspect~~example of the ~~invention~~present disclosure, step i) may also comprise adding a feedstock originating from a renewable source, as recited in connection with the first ~~aspect~~example of the ~~invention~~present disclosure.

In a third ~~aspect~~example, the ~~invention~~present disclosure is a plant, i.e. process plant, for producing a hydrocarbon product, comprising:

- a hydroprocessing section arranged to receive a feedstock originating from a renewable source and a compressed hydrogen-rich feed stream for producing a main hydrotreated stream;
- a separation section arranged to receive said main hydrotreated stream for producing an aqueous stream, a hydrogen-rich stream as a first recycle gas stream, an off-gas

stream comprising hydrocarbons as a second recycle stream, and said hydrocarbon product, boiling at above 50°C;

- a separation section, which is preferably at least one of an amine absorption stage, a caustic scrubber, and a sulfur absorbent, arranged to receive said off-gas stream, for removing H_2S and thereby producing said second recycle gas stream;
- a hydrogen producing unit (HPU) arranged to receive said second recycle gas stream and a hydrocarbon feedstock for producing a make-up hydrogen stream;
- a compressor section arranged to receive said first recycle gas stream and at least a portion of the make-up hydrogen stream produced in said HPU, for generating said compressed hydrogen-rich feed stream and a make-up hydrogen recycle stream;
- a conduit for passing said first recycle gas stream to said compressor section;
- a conduit for passing said make-up hydrogen stream from the HPU to said compressor section;
- optionally a conduit for recycling said make-up hydrogen recycle stream to the HPU.
- optionally means for splitting said hydrogen-rich stream into said first recycle gas stream and a third recycle gas stream, and a conduit for passing said third recycle gas stream to said HPU.

Any of the above ~~embodiment~~examples of the first ~~aspect~~example of the ~~invention~~ present disclosure may be used together with the second ~~aspect~~example and third ~~aspect~~example of the ~~invention~~present disclosure. It would be understood, that any of the associated benefits of the above ~~embodiment~~examples of the first ~~aspect~~example of the ~~invention~~present disclosure may also be used together with the second ~~aspect~~example and third ~~aspect~~example of the ~~invention~~present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic flow diagram of the overall process/plant, i.e. integrated process/plant, according to a specific embodiment of the invention.

Fig. 2 shows a schematic flow diagram of the overall process/plant according to another specific embodiment of the invention.