to remove $H_2S/CO/CO_2$ from the H_2-rich stream. The thus cleaned H_2-rich stream is then fed to the hydrogen plant. This citation is at least silent about providing hydrogen to the hydrogen plant from an off-gas produced farther downstream.

SUMMARY

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

i) passing a solid renewable feedstock through a thermal decomposition section, for producing:

a first off-gas stream comprising hydrocarbons, and a liquid oil stream;

ii) passing the liquid oil stream through a hydroprocessing section for producing a main hydroprocessed stream;

iii) passing the main hydroprocessed stream to a separation section for producing:

an aqueous stream,

a hydrogen-rich stream,

a second off-gas stream comprising hydrocarbons,

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

iv) passing the hydrogen-rich stream to the hydroprocessing section;

v) passing the first off-gas stream from step i) and/or the second off-gas stream from step iii) to a hydrogen producing unit, for producing a make-up hydrogen stream;

vi) passing the make-up hydrogen stream to the hydroprocessing section;

wherein in step iii) the separation section comprises:

iii-1) passing the main hydrotreated stream to a separator for producing said aqueous stream, said hydrogen-rich stream, and a heavy hydrocarbon stream;

iii-2) passing the heavy hydrocarbon stream to a fractionation section for producing said second off-gas stream and said hydrocarbon product;

and

wherein prior to conducting step v), said second off-gas stream from step iii) passes to a separation unit for removing H_2S;

and

wherein the hydrogen-rich stream (of step iii) is not subjected to a separation stage for removing H_2S and/or CO_2 prior to being passed to the hydroprocessing section.

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

- a thermal decomposition section arranged to receive a solid renewable feedstock for producing a first off-gas stream comprising hydrocarbons, and a liquid oil stream;
- a hydroprocessing section arranged to receive said liquid oil stream and a compressed hydrogen-rich 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, a second off-gas stream comprising hydrocarbons, and said hydrocarbon product, boiling at above 50°C; wherein the separation section comprises:

a separator arranged to receive the main hydrotreated stream for producing said aqueous stream, said hydrogen-rich stream, and a heavy hydrocarbon stream;

a fractionation section arranged to receive the heavy hydrocarbon stream for producing said second off-gas stream and said hydrocarbon product;

- a separation unit for removing H_2S, arranged to receive said second off-gas stream;
- a hydrogen producing unit (HPU) arranged to receive said first off-gas stream and/or said second off-gas stream for producing a make-up hydrogen stream;
- a compressor section arranged to receive said hydrogen-rich stream and at least a portion of the make-up hydrogen stream produced in said HPU, for generating said compressed hydrogen-rich stream and a make-up hydrogen recycle stream;
- a conduit for passing said first off-gas stream to said HPU;
- a conduit for passing said hydrogen-rich stream to said compressor section, in which there is no separation unit for removing H_2S and/or CO_2, optionally also for removing NH_3 and/or CO, from said hydrogen-rich stream, upstream said hydroprocessing 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 for forming a split hydrogen-rich stream, and a conduit for passing said split hydrogen-rich stream to said HPU.

The integration of a hydroprocessing stage with a dedicated hydrogen production unit is very important for minimizing the carbon dioxide emissions, but in order to reduce such emissions, the consumption of natural gas, which is normally used as hydrocarbon feed in the hydrogen producing unit, needs to be significantly reduced. While the above integration reduces the total consumption of hydrogen and thereby the natural gas consumption, it would be desirable to be able to replace most or all of the natural gas used in the hydrogen producing unit. However, replacing the natural gas for the hydrogen production requires a sacrifice of naphtha generated in the hydroprocessing, since this is used as hydrocarbon feed in the hydrogen production unit, thereby impairing the potential use of the naphtha for either gasoline or petrochemical production.

We have found that apart from the reduction of the total consumption of hydrogen, it is now also possible to integrate a thermal decomposition section such as a pyrolysis section and a hydroprocessing section and downstream separation section, together with a hydrogen production unit and minimize the energy consumption for the overall process/plant i.e. plant comprising said pyrolysis, hydroprocessing/separation and hydrogen producing unit, mainly by minimizing or eliminating the natural gas consumption for producing hydrogen required for hydroprocessing of the renewable feed, thereby drastically reducing the carbon dioxide footprint of the plant.

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

i) passing a solid renewable feedstock through a thermal decomposition section, such as a pyrolysis section, e.g. a fast pyrolysis section, for producing:

a first off-gas stream, such as a pyrolysis off-gas stream, comprising hydrocarbons, and a liquid oil stream, such as a pyrolysis oil stream;

ii) passing the liquid oil stream through a hydroprocessing section for producing a main hydroprocessed stream;

CLAIMS

1. A process for producing a hydrocarbon product, said process comprising the steps of:

i) passing a solid renewable feedstock through a thermal decomposition section, for producing:

a first off-gas stream comprising hydrocarbons, and a liquid oil stream;

ii) passing the liquid oil stream through a hydroprocessing section for producing a main hydroprocessed stream;

iii) passing the main hydroprocessed stream to a separation section for producing:

an aqueous stream,

a hydrogen-rich stream,

a second off-gas stream comprising hydrocarbons,

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

iv) passing the hydrogen-rich stream to the hydroprocessing section;

v) passing the first off-gas stream from step i) and/or the second off-gas stream from step iii) to a hydrogen producing unit, for producing a make-up hydrogen stream;

vi) passing the make-up hydrogen stream to the hydroprocessing section;

wherein in step iii) the separation section comprises:

iii-1) passing the main hydrotreated stream to a separator for producing said aqueous stream, said hydrogen-rich stream, and a heavy hydrocarbon stream;

iii-2) passing the heavy hydrocarbon stream to a fractionation section for producing said second off-gas stream and said hydrocarbon product;

and

wherein prior to conducting step v), said second off-gas stream from step iii) passes to a separation unit for removing H_2S;

and

wherein the hydrogen-rich stream (of step iii) is not subjected to a separation stage for removing H_2S and/or CO_2 prior to being passed to the hydroprocessing section.

2. The process according to claim 1, wherein said separation unit is at least one of an amine absorption unit, a caustic scrubber, and a sulfur absorbent unit.

3. The process according to any of claims 1-2, wherein the hydrogen-rich stream (of step iii) is not subjected to a separation stage also for removing NH_3 and/or CO, prior to being passed to the hydroprocessing section, in particular prior to being passed to a first catalytic hydrotreating unit therein.

4. The process according to any of claims 1-3, wherein the thermal decomposition section is a pyrolysis section, thereby producing said first off-gas stream as a pyrolysis off-gas stream and said liquid oil stream as a pyrolysis oil stream.

5. The process according to claim 4, wherein the pyrolysis section is a fast pyrolysis section.

6. The process according to any of claims 1-5, wherein the thermal decomposition section is hydrothermal liquefaction.

7. The process according to any of claims 1-6, wherein the process further comprises:
vii) splitting said hydrogen-rich stream for forming a split hydrogen-rich stream and passing said split hydrogen-rich stream to said hydrogen producing unit.

8. The process according to any of claims 1-7, wherein in step ii) the hydroprocessing section comprises:
ii-1) passing the liquid oil stream through a first catalytic hydrotreating unit under the addition of hydrogen for producing a first hydrotreated stream;
ii-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;
and
wherein between step ii-1) and ii-2) the process further comprises passing the first hydrotreated stream to a 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.

9. The process according to claim 8, wherein the separator is a high-pressure or low-pressure separator.

10. The process according to claim 9, wherein in step vi) the make-up hydrogen stream passes to at least one of:
said first catalytic hydrotreating unit;
said separator between step ii-1) and ii-2); and
second catalytic hydrotreating unit;
and optionally also an additional catalytic hydrotreating unit.

11. The process according to claim 10, wherein:
the separator between step ii-1) and ii-2) is a high-pressure stripper; and/or
the additional catalytic hydrotreating unit, where present, is a third catalytic hydrotreating unit.

12. The process according to any of claims 1-11, wherein the separation section in step iii) also produces an LPG stream and the process further comprises feeding the LPG stream to the hydrogen producing unit.

13. The process according to any of claims 1-12, wherein the hydrogen producing unit comprises subjecting the first off-gas stream, the second off-gas stream and optionally the LPG stream 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 optionally hydrogen purification in a hydrogen purification unit.

14. The process according to any of claims 1-13, wherein the hydrogen-rich stream or split hydrogen-rich stream comprises hydrogen in a concentration of 50 vol.% or higher, and wherein any of said streams is passed through a hydrogen purification unit: prior to splitting said hydrogen-rich stream for forming said split hydrogen-rich stream, or prior to passing the hydrogen-rich stream to the hydroprocessing stage, or prior to passing said split hydrogen-rich stream to the hydrogen producing unit.

15. The process according to any of claims 13-14, wherein the hydrogen purification unit is the hydrogen purification unit of the hydrogen producing unit and said split hydrogen-rich stream is passed through this hydrogen purification unit.

16. The process according to claim 15, wherein the hydrogen purification unit is a Pressure Swing Adsorption unit (PSA unit), said PSA unit producing a PSA off-gas stream which is used as fuel in the steam reforming unit of the hydrogen producing unit, and/or in fired heaters in the hydrogen producing unit, and/or in fired heaters in any of the catalytic hydrotreating units of the hydroprocessing section, separation units of the separation section, and/or for steam production;
and
wherein the steam reforming unit is: a convection reformer, a tubular reformer, autothermal reformer, electrically heated steam methane reformer, or combinations thereof.

17. The process according to any of claims 1-16, wherein prior to passing the make-up hydrogen stream to the hydroprocessing section, the make-up hydrogen stream passes through a compressor section comprising a make-up compressor and optionally also a recycle compressor, the make-up compressor also generating a hydrogen recycle stream which is added to the hydrogen producing unit, preferably directly to the first off-gas stream and/or to the second off-gas stream entering the hydrogen producing unit, and/or to the cleaning unit of the hydrogen producing unit.

18. The process according to any of claims 1-17, wherein the solid renewable feedstock is:
- a lignocellulosic biomass including: wood products, forestry waste, and agricultural residue; and/or
- municipal waste, in particular the organic portion thereof, where the municipal waste is defined as a feedstock containing materials of items discarded by the public, optionally wherein the municipal waste is mixed municipal waste given the waste code 200301 in the European Waste Catalog.

19. A plant for producing a hydrocarbon product, comprising:
- a thermal decomposition section arranged to receive a solid renewable feedstock for producing a first off-gas stream comprising hydrocarbons, and a liquid oil stream;

- a hydroprocessing section arranged to receive said liquid oil stream and a compressed hydrogen-rich 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, a second off-gas stream comprising hydrocarbons, and said hydrocarbon product, boiling at above 50°C; wherein the separation section comprises:

a separator arranged to receive the main hydrotreated stream for producing said aqueous stream, said hydrogen-rich stream, and a heavy hydrocarbon stream;

a fractionation section arranged to receive the heavy hydrocarbon stream for producing said second off-gas stream and said hydrocarbon product;

- a separation unit for removing H_2S, arranged to receive said second off-gas stream;
- a hydrogen producing unit (HPU) arranged to receive said first off-gas stream and/or said second off-gas stream for producing a make-up hydrogen stream;
- a compressor section arranged to receive said hydrogen-rich stream and at least a portion of the make-up hydrogen stream produced in said HPU, for generating said compressed hydrogen-rich stream and a make-up hydrogen recycle stream;
- a conduit for passing said first off-gas stream to said HPU;
- a conduit for passing said hydrogen-rich stream to said compressor section, in which there is no separation unit for removing H_2S and/or CO_2, optionally also for removing NH_3 and/or CO, from said hydrogen-rich stream, upstream said hydroprocessing 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 for forming a split hydrogen-rich stream, and a conduit for passing said split hydrogen-rich stream to said HPU.

20. The plant according to claim 19, wherein:

the thermal decomposition section is a pyrolysis section; and/or

the separation unit for removing H_2S is at least one of an amine absorption unit, a caustic scrubber, and a sulfur absorbent unit.