Claims

1. A wax oil hydrogenation method, comprising the following steps:

   (1)bringing wax oil as feedstock and a hydrogen-containing gas into contact with a first hydro-treating catalyst under first hydro-treating conditions, dividing a first hydro-treated stream obtained through the contact into two parts, i.e., a first hydro-treated stream **A** and a first hydro-treated stream **B**, and performing gas-liquid separation of the first hydro-treated stream **A** to obtain a first hydro-treated gas-phase stream and a first hydro-treated liquid-phase stream;

   (2)bringing the first hydro-treated stream **B**, the first hydro-treated liquid-phase stream, and a hydrogen-containing gas into contact with a second hydro-treating catalyst under second hydro-treating conditions, to obtain a resultant hydro-treated stream; and

   (3)bringing the first hydro-treated gas-phase stream and light catalytic cracking cycle oil into contact with a hydrofining catalyst to have a hydrofining reaction under hydrofining conditions, to obtain a resultant hydro-fined stream.

2. The method according to claim 1, wherein the initial boiling point of the wax oil is 100-400℃, and the final boiling point of the wax oil is 405-650℃;

   preferably, the wax oil is selected from at least one of vacuum gas oil (VGO), coker gas oil (CGO), deasphalted oil (DAO), coal tar, direct coal liquefaction distillate (DCLD), indirect coal liquefaction distillate (ICLD), synthetic oil, and shale oil.

3. The method according to claim 1, wherein the initial boiling point of the light catalytic cracking cycle oil is 100-200℃, and the final boiling point of the light catalytic cracking cycle oil is 320-400℃;

   preferably, the weight ratio of the light catalytic cracking cycle oil to the wax oil is 0.1-3:1, more preferably is 0.3-1.1:1.

4. The method according to claim 1, wherein the first hydro-treating catalyst and the second hydro-treating catalyst contain a carrier and an active component respectively and independently, wherein, the active component is selected from at least one of VIB and/or VIII metal elements, and the carrier is alumina and/or silicon-containing alumina;

   preferably, based on the total weight of the first hydro-treating catalyst and measured in oxide, the content of the VIB metal element is 10-35wt%, and the content of the VIII

metal element is 3-15wt%;

preferably, based on the total weight of the second hydro-treating catalyst and measured in oxide, the content of the VIB metal element is 10-35wt%, and the content of the VIII metal element is 3-15wt%;

preferably, the specific surface area of the first hydro-treating catalyst is 100-650m^2/g, and the pore volume of the first hydro-treating catalyst is 0.15-0.6mL/g;

preferably, the specific surface area of the second hydro-treating catalyst is 100-650m^2/g, and the pore volume of the second hydro-treating catalyst is 0.15-0.6mL/g.

5. The method according to claim 1, wherein the first hydro-treating conditions and the second hydro-treating conditions respectively and independently include: reaction pressure: 3-19MPa, reaction temperature: 300-450℃, liquid hourly space velocity: 0.2-6h^{-1}, and volume ratio of hydrogen to oil: 100-2,000:1;

preferably, the first hydro-treating conditions and the second hydro-treating conditions respectively and independently include: reaction pressure: 4-17MPa, reaction temperature: 320-420℃, liquid hourly space velocity: 0.4-4h^{-1}, and volume ratio of hydrogen to oil: 400-1,500:1.

6. The method according to any of claims 1-5, wherein the hydro-treated gas-phase stream accounts for 5-95vol% of the hydrogen-containing gas in the step (1), preferably is 10-80vol%.

7. The method according to any of claims 1-5, wherein the first hydro-treated stream **A** accounts for 5-95wt% of the total weight of the first hydro-treated stream **A** and the first hydro-treated stream **B**, preferably is 10-80wt%.

8. The method according to any of claims 1-5, wherein the hydrofining catalyst contains a carrier and an active component, wherein, the active component is selected from at least one of VIB and/or VIII metal elements, and the carrier is alumina and/or silicon-containing alumina;

preferably, based on the total weight of the hydrofining catalyst and measured in oxide, the content of the VIB metal element is 10-35wt%, and the content of the VIII metal element is 3-15wt%;

preferably, the specific surface area of the hydrofining catalyst is 100-650m^2/g, and the pore volume of the hydro-treating catalyst is 0.15-0.6mL/g;

preferably, the hydrofining conditions include: reaction pressure: 3-19MPa, reaction temperature: 260-450℃, liquid hourly space velocity: 0.2-6h^{-1}, and volume ratio of hydrogen to oil: 100-2,000:1, further preferably the reaction temperature is 280-410℃.

9. The method according to any of claims 1-8, wherein the method further comprising: cutting the light catalytic cracking cycle oil to obtain a light fraction and a heavy fraction, wherein, the cutting temperature is 245-300℃; the step (3) comprises: bringing the first hydro-treated gas-phase stream, the heavy fraction, and a hydrogen-containing gas into contact with a first hydrofining catalyst to have a first hydrofining reaction under first hydrofining conditions, to obtain a first hydro-fined stream; then bringing the first hydro-fined stream, the light fraction, and a hydrogen-containing gas into contact with a second hydrofining catalyst to have a second hydrofining reaction under second hydrofining conditions;

   preferably, the temperature of the second hydrofining reaction is lower than the temperature of the first hydrofining reaction; further preferably, the temperature of the second hydrofining reaction is lower than the temperature of the first hydrofining reaction by 5-20℃.

10. The method according to any of claims 1-9, wherein the step (2) further comprises: treating the resultant hydro-treated stream by separation and fractionation to obtain a hydro-treated hydrogen-rich gas, a hydro-treated gas, a hydro-treated naphtha, a hydro-treated diesel oil, and a hydro-treated heavy fraction; the step (3) further comprises: treating the resultant hydro-fined stream by separation and fractionation to obtain a hydro-fined hydrogen-rich gas, a hydro-fined gas, a hydro-fined naphtha, and a hydro-fined diesel oil;

    preferably, the separation in the step (2) comprises high-pressure separation and low-pressure separation, the resultant hydro-treated stream is treated by high-pressure separation to obtain the hydro-treated hydrogen-rich gas and a hydro-treated high-pressure separated liquid-phase stream, and then the hydro-treated high-pressure separated liquid-phase stream is treated by low-pressure separation to obtain the hydro-treated gas and a hydro-treated liquid-phase stream, and the hydro-treated

liquid-phase stream is treated by fractionation to obtain the hydro-treated naphtha, the hydro-treated diesel oil, and the hydro-treated heavy fraction;

preferably, the separation in the step (3) comprises high-pressure separation and low-pressure separation, the resultant hydro-fined stream is treated by high-pressure separation to obtain the hydro-fined hydrogen-rich gas and a hydro-fined high-pressure separated liquid-phase stream, and then the hydro-fined high-pressure separated liquid-phase stream is treated by low-pressure separation to obtain the hydro-fined gas and a hydro-fined liquid-phase stream, and the hydro-fined liquid-phase stream is treated by fractionation to obtain the hydro-fined naphtha and the hydro-fined diesel oil;

preferably, the method further comprises: recycling the hydro-treated hydrogen-rich gas and the hydro-fined hydrogen-rich gas to provide required hydrogen-containing gas.

11. The method according to any of claim 1-9, wherein the method further comprising: mixing the resultant hydro-treated stream and the resultant hydro-fined stream to obtain a mixture flow, and then treating the mixture flow by separation and fractionation;

preferably, the mixture flow is treated by high-pressure separation to obtain a mixed hydrogen-rich gas and a mixed high-pressure separated liquid-phase stream, and then the mixed high-pressure separated liquid-phase stream is treated by low-pressure separation to obtain a mixed gas and a mixed liquid-phase stream, and the mixed liquid-phase stream is treated by fractionation to obtain a mixed naphtha, a mixed diesel oil, and a mixed heavy fraction;

preferably, the method further comprises: recycling the mixed hydrogen-rich gas to provide required hydrogen-containing gas.

12. A wax oil hydrogenation system, comprising:

a first hydro-treating unit (1);

a gas-liquid separator (2) configured to perform gas-liquid separation for a part of first hydro-treated stream obtained in the first hydro-treating unit (1) to obtain a first hydro-treated gas-phase stream and a first hydro-treated liquid-phase stream;

a second hydro-treating unit (3) configured to perform second hydro-treatment for the remaining part of the first hydro-treated stream and the first hydro-treated liquid-phase stream in it to obtain a resultant hydro-treated stream;

a light catalytic cracking cycle oil supply unit (4) configured to supply light catalytic

cracking cycle oil; and

a hydrofining unit (5) configured to perform hydrofining for the light catalytic cracking cycle oil supplied by the light catalytic cracking cycle oil supply unit (4) and the hydro-treated gas-phase stream in it to obtain a resultant hydro-fined stream.

13. The system according to claim 12, wherein the gas-liquid separator (2) comprises a reactant inlet, a liquid phase conduit, and a gas phase conduit; the reactant inlet of the gas-liquid separator (2) communicates with the outlet of the first hydro-treating unit (1), the first hydro-treated liquid-phase stream is led into the second hydro-treating unit (3) through the liquid phase conduit, and the first hydro-treated gas-phase stream is led into the hydrofining unit (5) through the gas phase conduit.

14. The system according to claim 12 or 13, wherein the system further comprising:

a hydro-treating separation unit comprising a hydro-treating high-pressure separator (61) and a hydro-treating low-pressure separator (62) that are connected in series, wherein, the outlet of the second hydro-treating unit (3) communicates with the inlet of the hydro-treating high-pressure separator (61) through a pipeline; the resultant hydro-treated stream is separated at a high pressure in the hydro-treating high-pressure separator (61) to obtain a hydro-treated hydrogen-rich gas and a hydro-treated high-pressure separated liquid-phase stream, and then the hydro-treated high-pressure separated liquid-phase stream is separated at a low pressure in the hydro-treating low-pressure separator (62) to obtain a hydro-treated gas and a hydro-treated liquid-phase stream;

a hydro-treating fractionation tower (7), wherein the inlet of the hydro-treating fractionation tower (7) communicates with the outlet of the hydro-treating low-pressure separator (62) through a pipeline, the hydro-treated liquid-phase stream is fractionated in the hydro-treating fractionation tower (7) to obtain a hydro-treated naphtha, a hydro-treated diesel oil, and a hydro-treated heavy fraction;

a hydrofining separation unit comprising a hydrofining high-pressure separator (81) and a hydrofining low-pressure separator (82) that are connected in series, wherein, the outlet of the hydrofining unit (5) communicates with the inlet of the hydrofining high-pressure separator (81) through a pipeline; the resultant hydro-fined stream is separated at a high pressure in the hydrofining high-pressure separator (81) to obtain a hydro-fined hydrogen-rich gas and a hydro-fined high-pressure separated liquid-phase stream, and

then the hydro-fined high-pressure separated liquid-phase stream is separated at a low pressure in the hydrofining low-pressure separator (82) to obtain a hydro-fined gas and a hydro-fined liquid-phase stream; and

a hydrofining fractionation tower (9), wherein the inlet of the hydrofining fractionation tower (9) communicates with the outlet of the hydrofining low-pressure separator (82) through a pipeline, the hydro-fined liquid-phase stream is fractionated in the hydrofining fractionation tower (9) to obtain a hydro-fined naphtha and a hydro-fined diesel oil.

15. The system according to claim 14, wherein the gas phase outlet of the hydro-treating high-pressure separator (61) and the gas phase outlet of the hydrofining high-pressure separator (81) communicate with the inlet of the first hydro-treating unit (1) and/or the inlet of the second hydro-treating unit (3) respectively and independently, to recycle the hydro-treated hydrogen-rich gas and the hydro-fined hydrogen-rich gas so as to provide hydrogen required for the system.

16. The system according to claim 12 or 13, wherein the system further comprising:

a mixing separation unit and a mixing fractionation tower (11), wherein, the mixing separation unit comprises a mixing high-pressure separator (101) and a mixing low-pressure separator (102) that are connected in series, and the outlet of the mixing low-pressure separator (102) communicates with the inlet of the mixing fractionation tower (11);

the outlet of the second hydro-treating unit (3) and the outlet of the hydrofining unit (5) communicate with the inlet of the mixing high-pressure separator (101); the resultant hydro-treated stream and the resultant hydro-fined stream are mixed and then separated at a high pressure in the mixing high-pressure separator (101) to obtain a mixed hydrogen-rich gas and a mixed high-pressure separated liquid-phase stream;

the mixed high-pressure separated liquid-phase stream is separated at a low pressure in the mixing low-pressure separator (102) to obtain a mixed gas and a mixed liquid-phase stream;

the mixed liquid-phase stream is fractionated in the mixing fractionation tower (11) to obtain a mixed naphtha, a mixed diesel oil, and a mixed heavy fraction;

preferably, the gas-phase outlet of the mixing high-pressure separator (101) communicates with the inlet of the first hydro-treating unit (1) and/or the inlet of the

second hydro-treating unit (3) to recycle the mixed hydrogen-rich gas so as to provide hydrogen required for the system.

17. The system according to any of claims 12-16, wherein the hydrofining unit (5) comprises a first hydrofining unit (51) and a second hydrofining unit (52) that are arranged in series;
the system further comprises: a light catalytic cracking cycle oil fractionation tower (12) arranged between the first hydrofining unit (51) and the light catalytic cracking cycle oil supply unit (4) to cut the light catalytic cracking cycle oil supplied by the light catalytic cracking cycle oil supply unit (4) into a light fraction and a heavy fraction;
the heavy fraction and the first hydro-treated gas-phase stream are hydro-fined in the first hydrofining unit (51) to obtain a first hydro-fined stream; the first hydro-fined stream and the light fraction are hydro-fined in the second hydrofining unit (52) to obtain the resultant hydro-fined stream.