Claims

1. A wax oil hydrocracking method, comprising:

(1) contacting wax oil and a hydrogen-containing material flow with a pre-hydrotreating catalyst under pre-hydrotreating conditions to obtain a pre-hydrotreated material flow;

(2) contacting the pre-hydrotreated material flow and a hydrogen-containing material flow with a first hydrocracking catalyst to perform a first hydrocracking reaction under first hydrocracking conditions to obtain a first hydrocracked material flow, and dividing the first hydrocracked material flow into flow **A** and flow **B**;

(3) contacting flow **B** and a hydrogen-containing material flow with a second hydrocracking catalyst to perform a second hydrocracking reaction under second hydrocracking conditions to obtain a second hydrocracked material flow, and then separating and fractionating the second hydrocracked material flow to obtain a hydrocracked tail oil product; and

(4) contacting flow **A**, at least a part of the hydrocracked tail oil product, and a hydrogen-containing material flow with a hydrogenation isocracking catalyst to perform a hydrogenation isocracking reaction under hydrogenation isocracking conditions to obtain a hydrogenation isocracked material flow, and then separating and fractionating the hydrogenation isocracked material flow.

2. The method according to claim 1, wherein flow **A** accounts for 5-95 wt % of the wax oil.

3. The method according to claim 2, wherein flow **A** accounts for 10-80 wt % of the wax oil.

4. The method according to claim 1, wherein the method further comprising: separating flow **A** by gas-liquid separation to obtain a first hydrocracked gas-phase material flow and a first hydrocracked liquid-phase material flow; introducing the first hydrocracked gas-phase material flow into the step (3) to carry out the second hydrocracking reaction; contacting the first hydrocracked liquid-phase material flow, at least a part of the hydrocracked tail oil product and the hydrogen-containing material flow with the hydrogenation isocracking catalyst in the step (4) to carry out the hydrogenation isocracking reaction;

the first hydrocracked liquid-phase material flow accounts for 5-95 wt % of the wax oil.

5. The method according to claim 4, wherein the first hydrocracked liquid-phase material flow accounts for 10-80 wt % of the wax oil.

6. The method according to claim 1, wherein a hydrocracked hydrogen-rich gas, a hydrocracked gas product, a hydrocracked naphtha product, a hydrocracked jet fuel product, a hydrocracked diesel oil product, and the hydrocracked tail oil product are obtained through the separation and fractionation in the step (3);

a hydrogenation isocracked hydrogen-rich gas, a hydrogenation isocracked gas product, a hydrogenation isocracked naphtha product, a hydrogenation isocracked jet fuel product, a hydrogenation isocracked diesel oil product, and a hydrogenation isocracked tail oil product are obtained through the separation and fractionation in the step (4).

7. The method according to claim 6, wherein the separation in the step (3) comprises high-pressure separation and low-pressure separation, the second hydrocracked material flow is separated by high-pressure separation to obtain a hydrocracked hydrogen-rich gas and a hydrocracked high-pressure separated liquid-phase material flow, then the hydrocracked high-pressure separated liquid-phase material flow is separated by low-pressure separation to obtain a hydrocracked gas product and a hydrocracked liquid-phase material flow, the hydrocracked liquid-phase material flow is fractionated to obtain a hydrocracked naphtha product, a hydrocracked jet fuel product, a hydrocracked diesel oil product, and the hydrocracked tail oil product;

the separation in the step (4) comprises high-pressure separation and low-pressure separation, the hydrogenation isocracked material flow is separated by high-pressure separation to obtain a hydrogenation isocracked hydrogen-rich gas and a hydrogenation isocracked high-pressure separated liquid-phase material flow, and then the hydrogenation isocracked high-pressure separated liquid-phase material flow is separated by low-pressure separation to obtain a hydrogenation isocracked gas product and a hydrogenation isocracked liquid-phase material flow, the hydrogenation isocracked liquid-phase material flow is fractionated to obtain a hydrogenation isocracked naphtha product, a hydrogenation isocracked jet fuel product, a hydrogenation isocracked diesel oil product, and a hydrogenation isocracked tail oil product;

the method further comprises: recycling the hydrocracked hydrogen-rich gas and the hydrogenation isocracked hydrogen-rich gas to provide required hydrogen-containing material flow.

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

the wax oil is selected from at least one of vacuum gas oil (VGO), coker gas oil (CGO),

deasphalted oil (DAO), catalytic cycle oil, coal tar, direct coal liquefaction distillate (DCLD), indirect coal liquefaction distillate (ICLD), synthetic oil, and shale oil;
wherein an initial boiling point of the hydrocracked tail oil product is 300-375℃.

9. The method according to claim 1, wherein the pre-hydrotreating catalyst contains a carrier and an active component, wherein, the active component is one or more VIB metal, one or more VIII metal, or mixtures thereof, and the carrier is alumina, silicon-containing alumina, or a mixture thereof;
wherein, based on the total weight of the pre-hydrotreating catalyst and measured in oxide, a content of the VIB metal element is 10-35 wt %, and a content of the VIII metal element is 3-15 wt %;
a specific surface area of the pre-hydrotreating catalyst is 100-650 m^2/g, and a pore volume of the pre-hydrotreating catalyst is 0.15-0.6 mL/g.

10. The method according to claim 1, wherein the pre-hydrotreating conditions include: reaction pressure: 3-19 MPa, reaction temperature: 300-450℃, liquid hourly space velocity: 0.2-6h^{-1}, and volume ratio of hydrogen to oil: 100-2,000:1.

11. The method according to claim 1, wherein the first hydrocracking catalyst and the second hydrocracking catalyst respectively and independently contain a carrier and an active constituent, wherein, the active constituent is one or more VIB metal, one or more VIII metal, or mixtures thereof, and the carrier contains a Y zeolite;
based on a total weight of the first hydrocracking catalyst and measured in oxide, a content of the VIB metal is 10-35 wt %, and a content of the VIII metal is 3-15 wt %; the content of the Y zeolite is 5-80 wt %;
based on a total weight of the second hydrocracking catalyst and measured in oxide, a content of the VIB metal is 10-35 wt %, and a content of the VIII metal is 3-15 wt %; and a content of the Y zeolite is 5-80 wt %.

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

13. The method according to claim 1, wherein the hydrocracked tail oil product in the step (4) accounts for 10-100 wt % of the hydrocracked tail oil product obtained in the step (3).

14. The method according to claim 1, wherein the hydrogenation isocracking catalyst contains a carrier and an active constituent, wherein, the active constituent is one or more of VIB metal, one or more of VIII metal, or mixtures thereof, and the carrier comprises a beta zeolite, a SAPO zeolite, or both; and

based on a total weight of the hydrogenation isocracking catalyst and measured in oxide, a content of the VIB metal is 10-35 wt %, a content of the VIII metal is 3-15 wt %, and a content of the beta zeolite, the SAPO zeolite, or the mixture thereof is 5-80 wt %.

15. The method according to claim 1, wherein the hydrogenation isocracking conditions include a reaction pressure of 3-19 MPa, a reaction temperature of 300-450℃, a liquid hourly space velocity of 0.2-6h^{-1}, and a volume ratio of hydrogen to oil of 100-2,000.

16. A wax oil hydrocracking system, comprising:

a pre-hydrotreating unit;

a first hydrocracking unit, in which a pre-hydrotreated material flow obtained from the pre-hydrotreating unit is treated by a first hydrocracking to obtain a first hydrocracked material flow;

a second hydrocracking unit, in which a part of the first hydrocracked material flow is treated by a second hydrocracking to obtain a second hydrocracked material flow;

a hydrocracking separation unit, in which the second hydrocracked material flow is separated to obtain a hydrocracked hydrogen-rich gas, a hydrocracked gas product, and a hydrocracked liquid-phase material flow;

a hydrocracking fractionation tower, in which the hydrocracked liquid-phase material flow is fractionated to obtain a hydrocracked tail oil product;

a hydrogenation isocracking reactor, in which a portion of the first hydrocracked material flow and at least a portion of the hydrocracked tail oil product are treated by hydrogenation isocracking to obtain a hydrogenation isocracked material flow;

a hydrogenation isocracking separation unit, in which the hydrogenation isocracked material flow is separated to obtain a hydrogenation isocracked hydrogen-rich gas, a hydrogenation isocracked gas product, and a hydrogenation isocracked liquid-phase material flow; and

a hydrogenation isocracking fractionation tower, in which the hydrogenation isocracked

liquid-phase material flow is fractionated.

17. The system according to claim 16, further comprising: a gas-liquid separator configured to perform gas-liquid separation of the portion of the first hydrocracked material flow to obtain a first hydrocracked gas-phase material flow and a first hydrocracked liquid-phase material flow, the first hydrocracked gas-phase material flow is fed into the second hydrocracking unit, and the first hydrocracked liquid-phase material flow is fed into the hydrogenation isocracking reactor.

18. The system according to claim 16, wherein the hydrocracking separation unit comprises a hydrocracking high-pressure separator and a hydrocracking low-pressure separator that are connected in series, the second hydrocracked material flow is separated in the hydrocracking high-pressure separator to obtain a hydrocracked hydrogen-rich gas and a hydrocracked high-pressure separated liquid-phase material flow; the hydrocracked high-pressure separated liquid-phase material flow is separated in the hydrocracking low-pressure separator to obtain a hydrocracked gas product and the hydrocracked liquid-phase material flow;
the hydrogenation isocracking separation unit comprises a hydrogenation isocracking high-pressure separator and a hydrogenation isocracking low-pressure separator, the hydrogenation isocracked material flow is separated in the hydrogenation isocracking high-pressure separator to obtain a hydrogenation isocracked hydrogen-rich gas and a hydrogenation isocracked high-pressure separated liquid-phase material flow; the hydrogenation isocracked high-pressure separated liquid-phase material flow is separated in the hydrogenation isocracking low-pressure separator to obtain a hydrogenation isocracked gas product and the hydrogenation isocracked liquid-phase material flow.

19. The system according to claim 18, wherein the gas phase outlet of the hydrocracking high-pressure separator and the gas phase outlet of the hydrogenation isocracking high-pressure separator respectively and independently communicate with at least one of the inlet of the pre-hydrotreating unit, an inlet of the first hydrocracking unit, an inlet of the second hydrocracking unit, and an inlet of the hydrogenation isocracking reactor, to recycle the hydrocracked hydrogen-rich gas and the hydrogenation isocracked hydrogen-rich gas so as to provide a hydrogen-containing material flow required for the system.

20. The system according to claim 16, wherein the pre-hydrotreating unit, the first hydrocracking

unit, and the second hydrocracking unit are arranged in one hydrogenation reactor; or

the pre-hydrotreating unit, the first hydrocracking unit, and the second hydrocracking unit are respectively arranged in different hydrogenation reactors; or

the pre-hydrotreating unit is arranged in one hydrogenation reactor, and the first hydrocracking unit and the second hydrocracking unit are arranged in another hydrogenation reactor.