Claims

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

a) Dividing the distillate oil feedstocks by sulfur content into high-sulfur distillate oil feedstocks and low-sulfur distillate oil feedstocks, processing the high-sulfur distillate oil feedstocks with gas-phase circulating hydrogenation technique, driving the material processed with gas-phase circulating hydrogenation technique into a high-pressure separator and separating the material to obtain gas phase material and liquid phase material, wherein, the sulfur content according to which the distillate oil feedstocks are divided into high-sulfur distillate oil feedstocks and low-sulfur distillate oil feedstocks is at any value within 1,000~12,000μg/g, and the sulfur content in the material processed with gas-phase circulating hydrogenation technique is lower than 100μg/g;

b) Feeding the liquid phase material obtained by separation in the high-pressure separator in step a) and the low-sulfur distillate oil feedstocks with dissolved hydrogen into a solid-liquid two-phase hydrogenation reactor in a solid-liquid two-phase hydrogenation unit for solid-liquid two-phase hydrotreating to obtain a hydrogenated distillate oil product, wherein, the solid-liquid two-phase hydro-processing doesn't use circulating oil.

2. The method according to claim 1, wherein, the sulfur content in the material processed with gas-phase circulating hydrogenation technique is lower than 60μg/g, preferably is lower than 50μg/g, more preferably is lower than 15μg/g, optimally is lower than 10μg/g.

3. The method according to claim 1, wherein, the material processed with gas-phase circulating hydrogenation technique undergoes a heat exchange procedure before it enters into the high-pressure separator.

4. The method according to claim 3, wherein, the heat exchange method comprises: controlling at least a part of the material processed with gas-phase circulating hydrogenation technique to undergo heat exchange with the high-sulfur distillate oil feedstocks.

5. The method according to claim 4, wherein, the material processed with gas-phase circulating hydrogenation technique is heated up before heat exchange, and the temperature of the high-sulfur distillate oil feedstocks after heat exchange reaches to the temperature required for the gas-phase circulating hydrogenation technique.

6. The method according to claim 5, wherein, the solid-liquid two-phase hydrogenation unit is not equipped with a heating furnace, the low-sulfur distillate oil feedstocks undergo heat exchange with the hydrogenated distillate oil product first, and then are directly mixed with the liquid phase material that flows out of the high-pressure separator, and the temperature of the mixture reaches to the required inlet temperature of the solid-liquid two-phase hydrogenation reactor.

7. The method according to claim 6, wherein, the operating temperature of the high-pressure separator is higher than the inlet temperature of the solid-liquid two-phase hydrogenation reactor by 5°C~150°C, preferably 10°C~80°C.

8. The method according to any of previous claims, wherein, the sulfur content according to which the distillate oil feedstocks are divided by sulfur content into high-sulfur distillate oil feedstocks and low-sulfur distillate oil feedstocks is at any value within 2,000~8,500μg/g.

9. The method according to any of previous claims, wherein, the high-sulfur distillate oil feedstocks come from secondarily processed distillate oils, including at least one selected from the group consisting of coked distillate oils, catalytic cracked distillate oils, and coal liquefied distillate oils; the low-sulfur distillate oil feedstocks

comprise straight-run distillate oils obtained from crude oil distillation.

10. The method according to any of previous claims, wherein, the high-sulfur distillate oil feedstocks and low-sulfur distillate oil feedstocks are at least one selected from the group consisting of kerosene distillates, diesel distillates, and VGO distillates.

11. The method according to any of previous claims, wherein, the distillation range of the high-sulfur distillate oil feedstocks and low-sulfur distillate oil feedstocks are 130~450°C, preferably 200~380°C.

12. The method according to any of previous claims, wherein, in step a), the reaction temperature of the gas-phase circulating hydrogenation technique is 100~400°C, preferably 260~380°C; the reaction pressure is 2.5~10.0MPa, preferably 4.0~8.0MPa; the volume ratio of hydrogen/oil is 50:1~1,000:1, preferably 300:1~800:1; the liquid hourly space velocity is 0.6~5.0h^{-1}, preferably 1.0~2.5h^{-1}.

13. The method according to any of previous claims, wherein, in step a), the gas-phase circulating hydrogenation technique employs a trickle bed reactor, ebullated bed reactor, expanded bed reactor, or counter-flow bed reactor.

14. The method according to any of previous claims, wherein, in step b), the solid-liquid two-phase hydrogenation reactor employs a top-charge and bottom-discharge operation mode or a bottom-charge and top-discharge operation mode; the operating conditions of the solid-liquid two-phase hydrogenation reactor described in step b) include: reaction temperature: 100~400°C, preferably 260~380°C; reaction pressure: 1.5~8.0MPa, preferably 2.0~6.0MPa; liquid hourly space velocity: 0.6~5.0h^{-1}, preferably 1.0~2.5h^{-1}; the volume mixing ratio of liquid phase material separated in the high-pressure separator / low-sulfur distillate oil feedstocks is 0.5:1~4.0:1, preferably 1.0:1~3.0:1.

15. The method according to any of previous claims, wherein, the reaction pressure of the gas-phase circulating hydrogenation technique is higher than the reaction pressure of the solid-liquid two-phase hydrogenation reactor by 1~4MPa.

16. The method according to any of previous claims, wherein, the catalyst used in step a) and step b) is a hydro-treating catalyst, the active metal component of the catalyst is at least one selected from the group consisting of nickel, cobalt, molybdenum, and tungsten, and the catalyst is sulfurized before it is used, to convert the active metal component into sulfurized state.

17. A distillate oil combined hydrogenation apparatus, comprising a gas-phase circulating hydrogenation reactor (1), a high-pressure separator (2), and a solid-liquid two-phase hydrogenation unit that are connected sequentially, wherein, the solid-liquid two-phase hydrogenation unit comprises a hydrogen dissolving device (3) for the feedstocks to be processed by solid-liquid two-phase hydrogenation and a solid-liquid two-phase hydrogenation reactor (4), the hydrogen dissolving device (3) for the feedstocks to be processed by solid-liquid two-phase hydrogenation has a separate feed inlet, the gas-phase circulating hydrogenation reactor (1) and the solid-liquid two-phase hydrogenation reactor (4) communicate with a separate fresh feedstock feeding device respectively, the liquid phase outlet pipeline of the high-pressure separator (2) communicates with the solid-liquid two-phase hydrogenation unit, and a circulating oil system is canceled in the solid-liquid two-phase hydrogenation unit.

18. The apparatus according to claim 17, wherein, a first heat exchanger (11) is arranged between the gas-phase circulating hydrogenation reactor (1) and the high-pressure separator (2), to accomplish heat exchange between the feedstocks and effluents of the gas-phase circulating hydrogenation reactor (1).

19. The apparatus according to claim 18, wherein, the gas-phase circulating hydrogenation reactor (1) further communicates directly with the high-pressure

separator (2) through another pipeline.

20. The apparatus according to claim 18 or 19, wherein, a heating device (10) is arranged between the gas-phase circulating hydrogenation reactor (1) and the first heat exchanger (11).

21. The apparatus according to claim 20, wherein, the hydrogen dissolving device (3) for the feedstocks to be processed by solid-liquid two-phase hydrogenation is arranged between the high-pressure separator (2) and the solid-liquid two-phase hydrogenation reactor (4).

22. The apparatus according to any of previous claims, wherein, the solid-liquid two-phase hydrogenation unit further comprises a second heat exchanger (12), to accomplish heat exchange between the feedstocks and the effluents of the solid-liquid two-phase hydrogenation unit.