

DIESEL OIL AND JET FUEL PRODUCTION SYSTEM AND METHOD UTILIZING FISCHER-TROPSCH SYNTHETIC OIL

FIELD OF THE INVENTION

[0001] The invention relates to the technical field of the deep processing of Fischer-Tropsch synthetic oil, and more particularly to a system and method for producing diesel fuel and jet fuel using Fischer-Tropsch synthetic oil.

BACKGROUND OF THE INVENTION

[0002] At present, the main energy source is fossil energy in the world. Petroleum is the main source of motor fuel. Petroleum belongs to nonrenewable energy, is drying up with each passing day and becomes increasingly heavier and poorer. Due to increasingly strict environmental protection laws and regulations, the sustainable economic growth of the world needs production of a lot of light clean fuel. All raise a demand for improving the current oil refining techniques, adding new substitutes for petroleum and manufacturing products that meet requirements at the lowest cost. Catalytic cracking is one of the important methods for turning heavy oil into light oil. However, due to the inferior and heavier catalytic cracking materials, the operating conditions become increasingly strict, and the yield and properties of light products become poor. The hydroprocessing technique of catalytic cracking materials can reduce the content of impurities such as sulfur, nitrogen and metal, improve the cracking performance of charged materials, lower the operating severity of FCC (fluid catalytic cracking), improve product distribution, increase target product selectivity, reduce the productivity of dry gas and coke, enhance the economic efficiency of FCC devices, reduce the sulfur content of targeted products and lower the content of Sox and NOx in regenerated flue gas.

[0003] China is a country which has abundant coal resources but lacks petroleum. In 2009, China imported 199 million-ton crude oil in total and China's oil dependency already exceeded 51.3%. It is predicated that China's oil dependency will exceed 60% in

2020. The fluctuations and changes of the international oil market will directly affect the economic and even political safety and stability of China. Solving the supply and demand problem of fluid fuel through non-petroleum synthetic fluid fuel not only meets the safety requirements of the national energy strategies but also plays an important role in guaranteeing the long-term stable and sustainable growth of national economy. Among many substitute energy techniques, the Fischer-Tropsch synthesis technique has become a popular technical development point of all countries and major petroleum companies. The material sources of Fischer-Tropsch synthesis are wide. Coal, natural gas, associated gas of oilfields and light-hydrocarbon and inferior residual oil of refineries can be used as production materials of synthesis gas.

[0004] The fluid fuel produced by adopting the Fischer-Tropsch synthesis technique features good combustion performance and little emission pollution and is called clean energy. Therefore, developing alternative energy sources for petroleum is one of the most feasible measures for solving the problems of short supply of petroleum and national energy safety. When the Fischer-Tropsch synthesis products can be turned into fluid fuel by high-efficient clean techniques on a large scale, the short supply of oil products will be effectively alleviated and promote continuous stable economic development.

Fischer-Tropsch synthesis products are quite different from oil products in terms of hydrocarbons and main nature, mainly comprise alkane and olefin and have an extremely low content of sulfur and nitrogen but a certain content of oxygen. Up-to-standard fluid fuel and chemicals can be obtained only after the corresponding hydro-upgrading of all fractions of Fischer-Tropsch synthesis. Generally, hydroprocessing of fluid hydrocarbons and synthetic wax can produce diesel fuel, jet fuel, gasoline, naphtha, refined wax and other products.

[0005] The Fischer-Tropsch synthetic oil is characterized by no sulfur, no nitrogen and no aromatic hydrocarbons and is an eco-friendly fuel oil and chemical. However, synthetic crude oil contains a lot of hydrocarbons and a certain amount of oxygenated compounds. In particular, acidic oxygenated compounds corrode equipment seriously and are not good for further processing and utilization of synthetic crude oil products. Therefore, proper methods must be adopted for hydrodeoxygenation and olefin saturation

of Fischer-Tropsch synthetic oil. As one of the main objectives of the Fischer-Tropsch synthesis technique, producing diesel fuel is an important task of synthetic oil plants. Some problems exist in producing diesel fuel by hydroprocessing of traditional low-temperature synthetic oil and high-temperature synthetic oil. Due to the characteristics of low-temperature synthetic oil, the hydroprocessed diesel fraction has a high condensation point and a low density and can't be sold as diesel products directly. Since high-temperature synthetic oil has a higher content of olefin and alkadiene, it is very easy to coke during hydroprocessing and thus the period of device operation is shortened.

[0006] Major research institutes have developed a plurality of relevant techniques for the hydro-upgrading of Fischer-Tropsch synthetic oil to improve the high-temperature and low-temperature Fischer-Tropsch synthetic oil. However, the known techniques have some shortcomings:

[0007] U. S. Pat. Pub. No. 6309432 discloses a method for processing and upgrading Fischer-Tropsch synthetic oil. First, the method separates Fischer-Tropsch synthetic oil into light and heavy fractions at 371°C. The light fraction lower than 371°C produces the fraction whose temperature ranges between 246°C and 371°C and the fraction whose temperature ranges between C5°C and 246°C after passing through the thermal separation system and the cold separation in succession. The fraction whose temperature ranges between 246°C and 371°C and the heavy fraction whose temperature is higher than 371°C passes through the hydro-isocracking reactor. During olefin saturation and hydrodeoxygenation, the hydroisomerization and hydrocracking of n-alkenes happen. The main products of isomerization are mono-methyl branching hydrocarbons. The fraction whose temperature ranges between C5°C and 246°C doesn't go through hydroprocessing but enters the fractionating column after mixing with the products from the hydrocracking reactor to obtain corresponding fractions like jet fuel by separation. Since Fischer-Tropsch synthetic oil has a higher content of olefin and oxygen, when Fischer-Tropsch synthetic oil has a direct contact with an isocracking catalyst, the stability and operation period of the catalyst is affected and the product quality is poorer.

[0008] Chinese Patent Publication No. CN15944509A discloses a method for adopting a Fe-based catalyst for hydro-conversion of Fischer-Tropsch synthesis heavy hydrocarbons or kettle bottom wax to produce naphtha and diesel products. The specific method is that the Fe-based catalyst and the Fischer-Tropsch synthesis heavy hydrocarbons or kettle bottom wax are mixed evenly in the storage tank, then are mixed with hydrogen and heated to a temperature of between 300°C and 400°C, and enter the suspension bed reactor for hydrocracking and isomerization reactions. The reaction pressure of hydro-conversion ranges between 3.0 MPa and 20.0 MPa; the reaction temperature of hydro-conversion ranges between 350°C and 500°C; the volume ratio of hydrogen to oil ranges between 300 and 1800; and the liquid hourly space velocity ranges between 0.1⁻¹ and 3.0 h⁻¹. The hydroprocessing of the suspension bed technique is weaker, the reaction conditions are strict and the product properties are poorer. In addition, the hydrofining reactor of the suspension bed adopts the upward material-feeding method. Therefore, it is difficult to avoid the problems that the bed temperature gradient and the pressure drop are greater, the top of the reactor is easy to coke, hydrogen needs to be circulated, a circulating hydrogen compressor needs to be provided, and the equipment investment and the operation cost are higher.

[0009] Chinese Patent Application No. CN200510068181.2 discloses an integrated method for hydro-upgrading of Fischer-Tropsch synthetic oil. The method mixes the full-range fractions of Fischer-Tropsch synthetic oil and hydrogen to enter a hydrofining reactor for hydrodeoxygenation and olefin saturation reactions under the action of hydrofining catalysts. The hydrofining synthetic oil after high-pressure and low-pressure separation in succession enters a fractionating column for separation. After light and heavy naphtha, kerosene and diesel fractions are separated out, tail oil at the bottom of fractionating column enters a hydrocracking reactor. Under the action of the hydro-isocracking catalyst, heavy fractions are converted into middle distillates to the greatest extent. The products of the hydrocracking reactor and the products of hydrofining reactions mix and then enter the fractionating column for separation to obtain target products after high-pressure and low-pressure separation in succession. The disadvantages of the invention are that an integrated process is adopted, the flexibility of

operation is less and the diesel yield is low when the invention is used to produce low-condensation point diesel.

[0010] U. S. Pat. Pub. No. 6858127 owned by Shell Company discloses a method for producing middle distillates. The method realizes hydrocracking of part of synthetic oil at least, then conducts hydrocracking of separated diesel fractions and tail oil and finally separates diesel fractions from the products. The condensation point of diesel fractions can drop to -28°C. The density of diesel fractions can only reach 0.78 g/cm³. However, the diesel fractions still can't meet the density requirements of the new diesel standard.

SUMMARY OF THE INVENTION

[0011] In view of the above-described problems, it is one objective of the invention to provide a system and method for producing diesel fuel and jet fuel using Fischer-Tropsch synthetic oil. The method comprises two stages which are hydrofining and hydro-upgrading. Fischer-Tropsch synthetic oil mixes with hydrogen first and then enters a hydrofining reactor. The products of the hydrofining reactor enter a fractionating column to produce naphtha fractions as ethylene pyrolysis materials. Diesel fractions enter a hydroisomerization reactor and tail oil enters a hydrocracking reactor. The products of the hydro-isocracking and hydrocracking reactors mix and then enter the hydro-isocracking reactor to produce aviation kerosene and diesel products. The tail oil enters a cracking reactor. Compared to the conventional refining-cracking techniques, the system and method of the invention can produce quality diesel, aviation kerosene and hydro-treated wax oil, feature the simple technique, the stable process, the low investment in equipment, the low cost, the long operating period and the high yield of diesel and aviation kerosene. The produced diesel, aviation kerosene and hydro-treated wax oil can be used as fuel or quality blending composition.

[0012] To achieve the above objective, in accordance with one embodiment of the invention, there is provided a system for producing diesel fuel and jet fuel using Fischer-Tropsch synthetic oil, the system comprising a hydrofining reactor, a hot high-pressure separator, a first rectifying column, a hydrocracking reactor, a

hydroisomerization reactor, a second rectifying column, a first mixing chamber and a second mixing chamber.

[0013] The hydrofining reactor comprises a raw material inlet and a hydrofining product outlet.

[0014] The hot high-pressure separator comprises a separated oil outlet and a hydrofining product inlet which is connected to the hydrofining product outlet.

[0015] The first rectifying column comprises a tail oil fraction outlet, a diesel fraction outlet and a separated oil inlet which is connected to the separated oil outlet.

[0016] The first mixing chamber comprises a circulating hydrogen inlet, a first mixture outlet and a tail oil fraction inlet which is connected to the tail oil fraction outlet.

[0017] The hydrocracking reactor comprises a hydrocracking product outlet and a first mixture inlet which is connected to the first mixture outlet.

[0018] The second mixture chamber comprises a renewal hydrogen inlet, a second mixture outlet and a diesel fraction inlet connected to the diesel fraction outlet.

[0019] The hydroisomerization reactor comprises a hydroisomerization product outlet and a second mixture inlet which is connected to the second mixture outlet.

[0020] The second rectifying column comprises an aviation kerosene outlet, a diesel outlet and a hydrogenation product mixture inlet which is connected to the hydrocracking product outlet and the hydroisomerization product outlet.

[0021] In a class of this embodiment, the system also comprises a condensation fractionating column. The condensation fractionating column comprises a gas inlet, a fourth gas outlet and a liquid outlet.

[0022] The hot high-pressure separator further comprises a first gas outlet. The first rectifying column further comprises a second gas outlet. The second rectifying column further comprises a third gas outlet.

[0023] The first gas outlet of the hot high-pressure separator, the second gas outlet of the first rectifying column and the third gas outlet of the second rectifying column each

connect to the gas inlet of the condensation fractionating column. The fourth gas outlet of the condensation fractionating column is connected to the raw material inlet of the hydrofining reactor.

[0024] The second rectifying column further comprises a naphtha fraction outlet and a discharge pipe of the tail oil fraction and paraffin. The first rectifying column further comprises a naphtha fraction outlet. The discharge pipe of the tail oil fraction and paraffin is connected to the tail oil inlet of the first mixing chamber. The discharge pipe of the tail oil fraction and paraffin is connected to a paraffin outlet through a tee joint.

[0025] The pipe between the fourth gas outlet and the raw material inlet of the hydrofining reactor is connected to an oil mixture inlet pipe and a circulating hydrogen inlet pipe.

[0026] In another aspect, one embodiment of the invention also provides a method for producing diesel fuel and jet fuel using the system, the method comprising the following steps:

[0027] Step 1: transporting Fischer-Tropsch synthetic oil to the pipe through an oil mixture inlet pipe, introducing circulating hydrogen to the pipe through the circulating hydrogen inlet pipe, mixing and inputting the circulating hydrogen and the Fischer-Tropsch synthetic oil to the hydrofining reactor via the raw material inlet for a hydrofining reaction in the presence of a hydrofining catalyst to produce hydrofining products;

[0028] Step 2: allowing the hydrofining products to enter the hot high-pressure separator via the hydrofining product inlet to produce separated oil and cracking oil gas; discharging the separated oil via the separated oil outlet and introducing the separated oil to the first rectifying column via the separated oil inlet, discharging the cracking oil gas via the first gas outlet of the hot high-pressure separator;

[0029] Step 3: rectifying the separated oil in Step 2 to yield tail oil, diesel and naphtha fractions and cracking oil gas in the first rectifying column; discharging the tail oil fraction through the tail oil fraction outlet and allowing the tail oil fraction to enter the first mixing chamber through the tail oil fraction inlet; allowing the circulating hydrogen

to enter the first mixing chamber through the circulating hydrogen inlet; mixing the tail oil fraction and the circulating hydrogen in the first mixing chamber and allowing a resulting mixture to enter the hydrocracking reactor through the first mixture outlet and the first mixture inlet; discharging the diesel fraction through the diesel fraction outlet and allowing the diesel fraction to enter the second mixing chamber through the diesel fraction inlet; introducing renewal hydrogen to enter the second mixing chamber through the renewal hydrogen inlet; mixing the diesel fraction and the renewal hydrogen in the second mixing chamber and allowing a resulting mixture to enter the hydroisomerization reactor through the second mixture outlet and the second mixture inlet; and discharging the cracking oil gas through the second gas outlet;

[0030] Step 4: hydrocracking the tail oil fraction and the circulating hydrogen in the hydrocracking reactor to produce hydrocracking products; hydroisomerizing the diesel fraction and the renewal hydrogen in the hydroisomerization reactor to produce hydroisomerization products;

[0031] Step 5: discharging the hydrocracking products through the hydrocracking product outlet; discharging the hydroisomerization products through the hydroisomerization product outlet; mixing the hydrocracking products and the hydroisomerization products and allowing a resulting mixture to enter the second rectifying column through the hydrogenation product mixture inlet; rectifying the mixture of the hydrocracking products and the hydroisomerization products to produce cracking oil gas, aviation kerosene, diesel, paraffin, the tail oil fraction and the naphtha fraction in the second rectifying column; guiding the aviation kerosene to an aviation kerosene tank through the aviation kerosene outlet, guiding the diesel to a diesel tank through the diesel outlet; guiding the naphtha fraction to a naphtha fraction tank through the naphtha fraction outlet;

[0032] when aviation kerosene and diesel are the main products, guiding a mixture of the tail oil fraction and paraffin along the discharge pipe of the tail oil fraction and paraffin to enter the first mixing chamber via the tail oil fraction inlet to mix with the circulating hydrogen, and then enter the hydrocracking reactor; when paraffin is the main product, discharging the mixture of the tail oil fraction and paraffin through the paraffin

outlet; and discharging the produced cracking oil gas through the third gas outlet of the second rectifying column; and

[0033] Step 6: mixing and introducing the discharged cracking oil gas in steps 2, 3 and 5 to the condensation fractionating column via the gas inlet, to yield gas and liquid; discharging the gas via the fourth gas outlet and then allowing the gas to enter the hydrofining reactor via the raw material inlet for cyclic utilization; and discharging the liquid via the liquid outlet and then converging the liquid with the naphtha fraction to yield ethylene pyrolysis materials.

[0034] The system and method of the invention ensure the hydroisomerization reactions of diesel and aviation kerosene in a moderate operating condition thus reducing cracking reactions to the greatest extent and achieving the highest yield of diesel and aviation kerosene. The wax oil fraction passes through the reactor with a catalyst having hydrocracking and isomerization functions for hydrocracking and isomerization reactions to produce diesel that meets the national standard IV for diesel and 3# aviation kerosene and the yield of diesel and aviation kerosene is high. In addition, the method can also produce paraffin, can adjust production plans according to production requirements, and overcomes the shortcomings of the tradition proposals introduced in the background art which includes short operating period, poor product quality, strict reaction conditions, less flexibility of operation and low yield of diesel. The diesel and aviation kerosene produced by the invention have a high yield. The cetane number of the diesel can exceed 60; the condensation point of the diesel is less than 0°C; and the diesel can be used as a diesel blending composition or a diesel product. The smoke point of the aviation kerosene is greater than 25 mm; the freezing temperature of the aviation kerosene is less than -47°C; and the aviation kerosene can be used as 3# jet fuel or a blending composition. The technical method has the advantages that the flow is simple, the reaction condition is moderate, the production plan is flexible, the operating cost is low and it is easy to apply the method in industrial production.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] FIG. 1 is a structural diagram of a system for producing diesel fuel and jet fuel using Fischer-Tropsch synthetic oil in accordance with one embodiment of the invention.

[0036] Legends: **A**. Hydrofining Reactor, **A1**. Raw Material Inlet, **A2**. Hydrofining Product Outlet, **B**. Hot High-pressure Separator, **B1**. Hydrofining Product Inlet, **B2**. Separated Oil Outlet, **B3**. First Gas Outlet, **C**. First Rectifying Column, **C1**. Separated Oil Inlet, **C2**. Tail Oil Fraction Outlet, **C3**. Diesel Fraction Outlet, **C4**. Naphtha Fraction Outlet, **C5**. Second Gas Outlet, **D**. Hydrocracking Reactor, **D1**. Hydrocracking Product Outlet, **D2**. First Mixture Inlet, **E**. Hydroisomerization Reactor, **E1**. Hydroisomerization Product Outlet, **E2**. Second Mixture Inlet, **F**. Second Rectifying Column, **F1**. Hydrogenation Product Mixture Inlet, **F2**. Third Gas Outlet, **F3**. Naphtha Fraction Outlet, **F4**. Aviation Kerosene Outlet, **F5**. Diesel Outlet, **F6**. Discharge Pipe of Tail Oil Fraction and Paraffin, **F7**. Paraffin Outlet, **G**. condensation Fractionating Column, **G1**. Gas Inlet, **G2**. Fourth Gas Outlet, **G3**. Liquid Outlet, **H**. Second Mixing Chamber, **H1**. Mixture Outlet, **H2**. Renewal hydrogen inlet, **H3**. Diesel Fraction Inlet, **I**. First Mixing Chamber, **I1**. First Mixture Outlet, **I2**. Circulating Hydrogen Inlet, **I3**. Tail Oil Fraction Inlet, **J**. Oil Mixture Inlet Pipe, **K**. Circulating Hydrogen Inlet Pipe.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0037] The invention is further illustrated with the following figure and embodiments.

[0038] The system for producing diesel fuel and jet fuel using Fischer-Tropsch synthetic oil in FIG. 1 comprises a hydrofining reactor **A**, a hot high-pressure separator **B**, a first rectifying column **C**, a hydrocracking reactor **D**, a hydroisomerization reactor **E**, a second rectifying column **F**, a first mixing chamber **I** and a second mixing chamber **H**.

[0039] The hydrofining reactor **A** comprises a raw material inlet **A1** and a hydrofining product outlet **A2**.

[0040] The hot high-pressure separator **B** comprises a separated oil outlet **B2** and a hydrofining product inlet **B1** which is connected to the hydrofining product outlet **A2**.

[0041] The first rectifying column **C** comprises a tail oil fraction outlet **C2**, a diesel fraction outlet **C3** and a separated oil inlet **C1** which is connected to the separated oil outlet **B2**.

[0042] The first mixing chamber **I** comprises a circulating hydrogen inlet **I2**, a first mixture outlet **I1** and a tail oil fraction inlet **I3** which is connected to the tail oil fraction outlet **C2**.

[0043] The hydrocracking reactor **D** comprises a hydrocracking product outlet **D1** and a first mixture inlet **D2** which is connected to the first mixture outlet **I1**.

[0044] The second mixture chamber **H** comprises a renewal hydrogen inlet **H2**, a second mixture outlet **H1** and a diesel fraction inlet **H3** connected to the diesel fraction outlet **C3**.

[0045] The hydroisomerization reactor **E** comprises a hydroisomerization product outlet **E1** and a second mixture inlet which connects **E2** with the second mixture outlet **H1**.

[0046] The second rectifying column **F** comprises an aviation kerosene outlet **F4**, a diesel outlet **F5** and a hydrogenation product mixture inlet **F1** which is connected to hydrocracking product outlet **D1** and the hydroisomerization product outlet **E1**.

[0047] In the technical proposal, the system comprises a condensation fractionating column **G**. The condensation fractionating column **G** comprises a gas inlet **G1**, a fourth gas outlet **G2** and a liquid outlet **G3**.

[0048] The hot high-pressure separator **B** further comprises a first gas outlet **B3**. The first rectifying column **C** further comprises a second gas outlet **C5**. The second rectifying column **F** further comprises a third gas outlet **F2**.

[0049] The first gas outlet **B3** of the hot high-pressure separator **B**, the second gas outlet **C5** of the first rectifying column **C** and the third gas outlet **F2** of the second rectifying column **F** each connect to the gas inlet **G1** of the condensation fractionating column **G**. The fourth gas outlet **G2** of the condensation fractionating column **G** is connected to the raw material inlet **A1** of the hydrofining reactor **A**.

[0050] The second rectifying column **F** further comprises a naphtha fraction outlet **F3** and a discharge pipe **F6** for cyclic utilization of the tail oil fraction and paraffin. The first rectifying column **C** further comprises a naphtha fraction outlet **C4**. The discharge pipe **F6** of the tail oil fraction and paraffin is connected to the tail oil inlet **I3** of the first mixing chamber **I**. The discharge pipe **F6** of the tail oil fraction and paraffin is connected to a paraffin outlet **F7** through a tee joint. (The design can improve the flexibility of production. When more aviation kerosene and diesel products need to produce, the mixture of tail oil fraction and paraffin produced in Step 5 (More than 95% of the mixture is paraffin) is discharged through the discharge pipe **F6** of the tail oil fraction and paraffin, then enters the first mixing chamber **I** through the tail oil fraction inlet **I3** to mix with the circulating hydrogen, and finally enters the hydrocracking reactor **D**. When paraffin products need to produce, the mixture of tail oil fraction and paraffin produced in Step 5 is discharged through the paraffin outlet **F7**).

[0051] The pipe **M** between the fourth gas outlet **G2** and the raw material inlet **A1** of the hydrofining reactor **A** is connected to an oil mixture inlet pipe **J** and a circulating hydrogen inlet pipe **K**.

[0052] The method for producing diesel fuel and jet fuel using the system comprises the following steps:

[0053] Step 1: The Fischer-Tropsch synthetic oil is transported to the pipe **M** through an oil mixture inlet pipe **J**. The circulating hydrogen is transported to the pipe **M** through the circulating hydrogen inlet pipe **K**. The circulating hydrogen and the Fischer-Tropsch synthetic oil fully mix and enter the hydrofining reactor **A** through the raw material inlet **A1** for the hydrofining reaction in the presence of a hydrofining catalyst to produce hydrofining products.

[0054] Step 2: The hydrofining products in Step 1 enter the hot high-pressure separator **B** through the hydrofining product inlet **B1** to produce separated oil and cracking oil gas. The separated oil is discharged through the separated oil outlet **B2** and then enters the first rectifying column **C** through the separated oil inlet **C1**. The cracking oil gas is discharged through the gas outlet **B3** of the hot high-pressure separator **B**.

[0055] Step 3: The separated oil in Step 2 is rectified into tail oil, diesel and naphtha fractions and cracking oil gas through the first rectifying column **C**. The tail oil fraction is discharged through the tail oil fraction outlet **C2** and enters the first mixing chamber **I** through the tail oil fraction inlet **I3**. The circulating hydrogen enters the first mixing chamber **I** through the circulating hydrogen inlet **I2**. The tail oil fraction and the circulating hydrogen mix in the first mixing chamber **I** and then enter the hydrocracking reactor **D** through the first mixture outlet **I1** and the first mixture inlet **D2**. The diesel fraction is discharged through the diesel fraction outlet **C3** and enters the second mixing chamber **H** through the diesel fraction inlet **H3**. Renewal hydrogen enters the second mixing chamber **H** through the renewal hydrogen inlet **H2**. The diesel fraction and the renewal hydrogen mix in the second mixing chamber **H** and then enter the hydroisomerization reactor **E** through the second mixture outlet **H1** and the second mixture inlet **E2**. The cracking oil gas is discharged through the second gas outlet **C5**.

[0056] Step 4: In the hydrocracking reactor **D**, the tail oil fraction and the circulating hydrogen produce hydrocracking products through the hydrocracking reaction. In the hydroisomerization reactor **E**, the diesel fraction and the renewal hydrogen produce hydroisomerization products through the hydroisomerization reaction.

[0057] Step 5: The hydrocracking product is discharged through the hydrocracking product outlet **D1**. The hydroisomerization product is discharged through the hydroisomerization product outlet **E1**. The discharged hydrocracking product and the discharged hydroisomerization product mix and then enter the second rectifying column **F** through the hydrogenation product mixture inlet **F1**. The mixture of the hydrocracking and hydroisomerization products produces cracking oil gas, aviation kerosene, diesel, paraffin, the tail oil fraction and the naphtha fraction through the second rectifying column **F** (separate corresponding fractions according to different temperatures). The aviation kerosene is transported to the aviation kerosene tank through the aviation kerosene outlet **F4**. The diesel is transported to the diesel tank through the diesel outlet. The naphtha fraction is transported to the naphtha fraction through the naphtha fraction outlet **F3**. The naphtha fraction can be used as ethylene pyrolysis materials

[0058] When aviation kerosene and diesel are the main products, the produced mixture of the tail oil fraction and paraffin (Over 95% of the mixture is paraffin.) is discharged through the discharge pipe **F6** for cyclic utilization of the tail oil fraction and paraffin, enters the first mixing chamber **I** through the tail oil fraction inlet **I3** to mix with the circulating hydrogen, and then enters the hydrocracking reactor **D**. When paraffin is the main product, the produced mixture of the tail oil fraction and paraffin is discharged through the paraffin outlet **F7**, and enters the paraffin tank. The produced cracking oil gas in Step 5 is discharged through the third gas outlet **F2** of the second rectifying column **F**.

[0059] Step 6: The discharged cracking oil gas mixture in Steps 2, 3 and 5 enters the condensation fractionating column **G** through the gas inlet **G1**. Through condensation, gas and liquid are produced. The gas is discharged through the fourth gas outlet **G2** and then enters the hydrofining reactor **A** through the raw material inlet **A1** for cyclic utilization. The liquid is discharged through the liquid outlet **G3** and then converge with the naphtha fraction to serve as ethylene pyrolysis materials.

[0060] In the technical proposal, Fischer-Tropsch synthetic oil used in Step 1 comprises the low-temperature Fischer-Tropsch synthetic oil (ranging between 200°C and 240°C), or high-temperature Fischer-Tropsch synthetic oil (ranging between 250°C and 350°C), or part and/or full-range distillates of the oil mixture of the low-temperature Fischer-Tropsch synthetic oil and high-temperature Fischer-Tropsch synthetic oil.

[0061] The reaction conditions of the hydrofining reactor **A** in Step 1 of the technical proposal are as follows:

[0062] The reaction temperature ranges between 260°C and 400°C; the reaction pressure ranges between 2.0 MPa and 20.0 MPa; the liquid hourly space velocity ranges between 0.5 h⁻¹ and 3.0 h⁻¹; and the volume ratio of hydrogen to oil ranges between 500:1 and 2000:1.

[0063] The hydroisomerization reaction conditions in the hydroisomerization reactor **E** in Step 4 of the technical proposal are as follows:

[0064] The reaction temperature ranges between 280°C and 400°C; the reaction pressure ranges between 4.0 MPa and 15.0 MPa; the liquid hourly space velocity ranges

between 0.5 h^{-1} and 3.0 h^{-1} ; and the volume ratio of hydrogen to oil ranges between 500:1 and 2000:1.

[0065] The hydrocracking reaction conditions of the hydrocracking reactor **D** in Step 4 of the technical proposal are as follows:

[0066] The reaction temperature ranges between 280°C and 450°C ; the reaction pressure ranges between 5.0 MPa and 20.0 MPa; the liquid hourly space velocity ranges between 0.5 h^{-1} and 3.0 h^{-1} ; and the volume ratio of hydrogen to oil ranges between 500:1 and 2000:1.

[0067] The preferred hydrofining conditions of the hydrofining reactor **A** in Step 1 of the technical proposal are as follows:

[0068] The reaction temperature ranges between 280°C and 390°C ; the reaction pressure ranges between 4.0 MPa and 15.0 MPa; the liquid hourly space velocity ranges between 0.5 h^{-1} and 2.0 h^{-1} ; and the volume ratio of hydrogen to oil ranges between 500:1 and 1500:1.

[0069] The preferred hydroisomerization reaction conditions of the hydroisomerization reactor **E** in Step 4 of the technical proposal are as follows:

[0070] The reaction temperature ranges between 280°C and 370°C ; the reaction pressure ranges between 5.0 MPa and 12.0 MPa; the liquid hourly space velocity ranges between 0.5 h^{-1} and 2.0 h^{-1} ; and the volume ratio of hydrogen to oil ranges between 500:1 and 1500:1.

[0071] The preferred hydrocracking reaction conditions of the hydrocracking reactor **D** in Step 4 of the technical proposal are as follows:

[0072] The reaction temperature ranges between 320°C and 400°C ; the reaction pressure ranges between 5.0 MPa and 15.0 MPa; the liquid hourly space velocity ranges between 0.5 h^{-1} and 2.0 h^{-1} ; and the volume ratio of hydrogen to oil ranges between 700:1 and 1500:1.

[0073] The invention is specifically illustrated by taking the high and low-temperature synthetic distillates as raw materials. Refer to Table 1 for the properties of high and low-temperature synthetic distillates.

[0074] According to the process shown in FIG. 1, after hydrofining, the Fischer-Tropsch synthetic product is fractionated to produce dry gas, naphtha, diesel and heavy oil. The dry gas goes through the gas-liquid separator **G** as the circulating hydrogen. The naphtha fraction serves as ethylene pyrolysis materials. The diesel fraction enters the hydroisomerization reactor **E**. the heavy oil enters the hydrocracking reactor **D**.

Table 1 Properties of Full-range Low and High-temperature Synthetic Distillates

Items	Low temperature F-T synthetic oil	High temperature F-T synthetic oil
Density/g·cm ⁻³	0.7961	0.8224
Oxygen content/wt. %	6.8	10.2
Sulphur content/μg·g ⁻¹	<10	<10
Nitrogen content/μg·g ⁻¹	<10	<10
Olefin content/wt. %	26	54
Arene content/wt. %	3	27
Boiling range (ASTM-D1160)		
IBP/50%	52/378	69/153
90%/95%	562/>650	331/352

Example 1

[0075] The raw materials of the embodiment are low-temperature synthetic oil and the high-temperature synthetic oil. The ratio of the low-temperature synthetic oil to the high-temperature synthetic oil is 1: 1. The operating conditions of the hydrocracking reactor **D** are as follows: the reaction pressure is 5 MPa; the reaction temperature is 340°C, the liquid hourly space velocity is 0.8 h⁻¹ and the volume ratio of hydrogen to oil is 700: 1. The operating conditions of the hydroisomerization reactor **E** are as follows: the reaction temperature is 330°C, the reaction pressure is 5 MPa, the liquid hourly space velocity is 0.5 h⁻¹ and the volume ratio of hydrogen to oil is 700: 1. The hydrofining and

hydrocracking sections serve as comparison tests. The operating conditions and product properties are listed in Tables 2 and 3.

Table 2 Operating Conditions in Example 1 and Comparison example

Items	Example 1	Comparison example
Technical Process	Partial Circulation of the Tail Oil	Partial Circulation of the Tail Oil
Hydrofining/Hydrocracking/ Isomerism Catalyst	Hydrofining Agent 1/Hydrocracking Agent 1/Isomerism Agent 1	Hydrofining Agent 1/Hydrocracking Agent 1
Reaction Pressure/MPa	5.0	6.0
Refining/Modification/ Isomerism Liquid Hourly Space Velocity/ h ⁻¹	1.0/0.8/0.5	0.8/1.0
Refining/Modification/Isomerism Reaction Temperature/°C	320/350/330	320/360
Volume Ratio of Hydrogen to Oil	700: 1	700: 1

Table 3 Properties of Aviation Kerosene and Diesel

Item	Example 1	Comparison example
Aviation Kerosene		
Smoke Point/mm	26	22
Freezing Point/°C	<-48	-43°C
Density/g·cm ⁻³	0.7723	0.7835
Boiling Range (ASTM-D1160)		
IBP/10%	132/148	130/151
50%/90%	189/211	195/218
95%/EBP	236/258	240/267
Yield/%	37	26
Diesel		
Density /g·cm ⁻³	0.8046	0.7976
Condensation Point/°C	-21°C	-6°C
Cetane Number	61	64
Boiling Range (ASTM-D1160)		
IBP/10%	248/272	252/286
50%/90%	304/326	318/345
95%/EBP	341/358	358/379
Yield/%	37	23

Example 2

[0076] The raw materials of the embodiment are low-temperature synthetic oil and the high-temperature synthetic oil. The ratio of the low-temperature synthetic oil to the high-temperature synthetic oil is 2: 1. The operating conditions of the hydrocracking reactor **D** are as follows: the reaction pressure is 7 MPa; the reaction temperature is 375°C, the liquid hourly space velocity is 1.3 h⁻¹ and the volume ratio of hydrogen to oil is 900: 1. The operating conditions of the hydroisomerization reactor **E** are as follows: the reaction temperature is 350°C, the reaction pressure is 7 MPa, the liquid hourly space velocity is 1.0 h⁻¹ and the volume ratio of hydrogen to oil is 900: 1. The hydrofining and hydrocracking sections serve as comparison tests. The operating conditions and product properties are listed in Tables 4 and 5.

Table 4 Operating Conditions in Example 2 and Comparison example

Items	Example 2	Comparison example
Technical Process	Full Circulation of the Tail Oil	Full Circulation of the Tail Oil
Hydrofining/Hydrocracking/Isomerism Catalyst	Hydrofining Agent 2/Hydrocracking Agent 2/Isomerism Agent 2	Hydrofining Agent 2/Hydrocracking Agent 2
Reaction Pressure/MPa	7.0	10.0
Refining/Modification/Isomerism Liquid Hourly Space Velocity/ h ⁻¹	2.0/1.3/1.0	1.5/2.0
Refining/Modification/Isomerism Reaction Temperature/°C	350/370/350	350/370
Volume Ratio of Hydrogen to Oil	900: 1	900: 1

Table 5 Properties of Aviation Kerosene and Diesel

Items	Example 2	Comparison example
Aviation Kerosene		
Smoke Point/mm	28	24
Freezing Point/°C	<-50	-45
Density/g·cm ⁻³	0.7846	0.7985
Boiling Range (ASTM-D1160)		
IBP/10%	134/149	125/147

50%/90%	187/218	192/224
95%/EBP	234/251	246/263
Yield/%	30	20
Diesel		
Density/g·cm ⁻³	0.8075	0.8047
Condensation Point/°C	-16	-4
Cetane Number	64	65
Boiling Range (ASTM-D1160)		
IBP/10%	245/276	258/288
50%/90%	308/327	320/341
95%/EBP	341/356	352/368
Yield/%	66	46

[0077] As shown in Examples 1 and 2, compared to the current hydrofining—hydrocracking plans, the operating conditions of the technical plan are milder and the smoke point and freezing point of aviation kerosene can both meet the quality standard of 3# aviation kerosene, the product yield increases by over 10% and the cetane number is greater than 60. Although the cetane number is a little lower, the diesel yield increases by 20%.

[0078] The embodiments illustrate the advantages of the method of the invention more clearly and the level that the products of the invention can reach. According to the method of the invention, all compositions of Fischer-Tropsch synthetic oil are fully utilized. Compared to the ordinary technique for producing middle distillates by hydrocracking of Fischer-Tropsch synthetic wax, the method of the invention has the obvious advantages that the product quality is good and the yield is high.

[0079] Unless otherwise indicated, the numerical ranges involved in the invention include the end values. While particular embodiments of the invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

CLAIMS

1. A system for producing diesel fuel and jet fuel using Fischer-Tropsch synthetic oil, the system comprising a hydrofining reactor (A), a hot high-pressure separator (B), a first rectifying column (C), a hydrocracking reactor (D), a hydroisomerization reactor (E), a second rectifying column (F), a first mixing chamber (I), a second mixing chamber (H), and a condensation fractionating column (G); wherein

the hydrofining reactor (A) comprises a raw material inlet (A1) and a hydrofining product outlet (A2);

the hot high-pressure separator (B) comprises a separated oil outlet (B2) and a hydrofining product inlet (B1) which is connected to the hydrofining product outlet (A2);

the first rectifying column (C) comprises a tail oil fraction outlet (C2), a diesel fraction outlet (C3) and a separated oil inlet (C1) which is connected to the separated oil outlet (B2);

the first mixing chamber (I) comprises a circulating hydrogen inlet (I2), a first mixture outlet (I1) and a tail oil fraction inlet (I3) which is connected to the tail oil fraction outlet (C2);

the hydrocracking reactor (D) comprises a hydrocracking product outlet (D1) and a first mixture inlet (D2) which is connected to the first mixture outlet (I1);

the second mixture chamber (H) comprises a renewal hydrogen inlet (H2), a second mixture outlet (H1) and a diesel fraction inlet (H3) connected to the diesel fraction outlet (C3);

the hydroisomerization reactor (E) comprises a hydroisomerization product outlet (E1) and a second mixture inlet which connects (E2) with the second mixture outlet (H1);

the second rectifying column (F) comprises an aviation kerosene outlet (F4), a diesel outlet (F5) and a hydrogenation product mixture inlet (F1) which is connected to hydrocracking product outlet (D1) and the hydroisomerization product outlet (E1);

the condensation fractionating column (G) comprises a gas inlet (G1), a fourth gas outlet (G2) and a liquid outlet (G3);

the hot high-pressure separator (B) further comprises a first gas outlet (B3); the first rectifying column (C) further comprises a second gas outlet (C5); the second rectifying column (F) further comprises a third gas outlet (F2);

the first gas outlet (B3) of the hot high-pressure separator (B), the second gas outlet (C5) of the first rectifying column (C) and the third gas outlet (F2) of the second rectifying column (F) each connect to the gas inlet (G1) of the condensation fractionating column (G); the fourth gas outlet (G2) of the condensation fractionating column (G) is connected to the raw material inlet (A1) of the hydrofining reactor (A);

the second rectifying column (F) further comprises a naphtha fraction outlet (F3) and a discharge pipe (F6) for cyclic utilization of the tail oil fraction and paraffin; the first rectifying column (C) further comprises a naphtha fraction outlet (C4); the discharge pipe (F6) of the tail oil fraction and paraffin is connected to the tail oil inlet (I3) of the first mixing chamber (I); the discharge pipe (F6) of the tail oil fraction and paraffin is connected to a paraffin outlet (F7) through a tee joint; and

a pipe M between the fourth gas outlet (G2) and the raw material inlet (A1) of the hydrofining reactor (A) is connected to an oil mixture inlet pipe (J) and a circulating hydrogen inlet pipe (K).

2. A method for producing diesel fuel and jet fuel using the system of claim 1, the method comprising:

- 1) transporting Fischer-Tropsch synthetic oil to the pipe (M) through the

oil mixture inlet pipe (J), introducing circulating hydrogen to the pipe (M) through the circulating hydrogen inlet pipe (K), mixing and inputting the circulating hydrogen and the Fischer-Tropsch synthetic oil to the hydrofining reactor (A) via the raw material inlet (A1) for a hydrofining reaction in the presence of a hydrofining catalyst to produce hydrofining products;

2) allowing the hydrofining products to enter the hot high-pressure separator (B) via the hydrofining product inlet (B1) to produce separated oil and cracking oil gas; discharging the separated oil via the separated oil outlet (B2) and introducing the separated oil to the first rectifying column (C) via the separated oil inlet (C1), discharging the cracking oil gas via the first gas outlet (B3) of the hot high-pressure separator (B);

3) rectifying the separated oil in 2) to yield tail oil, diesel and naphtha fractions and cracking oil gas in the first rectifying column (C); discharging the tail oil fraction through the tail oil fraction outlet (C2) and allowing the tail oil fraction to enter the first mixing chamber (I) through the tail oil fraction inlet (I3); allowing the circulating hydrogen to enter the first mixing chamber (I) through the circulating hydrogen inlet (I2); mixing the tail oil fraction and the circulating hydrogen in the first mixing chamber (I) and allowing a resulting mixture to enter the hydrocracking reactor (D) through the first mixture outlet (I1) and the first mixture inlet (D2); discharging the diesel fraction through the diesel fraction outlet (C3) and allowing the diesel fraction to enter the second mixing chamber (H) through the diesel fraction inlet (H3); introducing renewal hydrogen to enter the second mixing chamber (H) through the renewal hydrogen inlet (H2); mixing the diesel fraction and the renewal hydrogen in the second mixing chamber (H) and allowing a resulting mixture to enter the hydroisomerization reactor (E) through the second mixture outlet (H1) and the second mixture inlet (E2); and discharging the cracking oil gas through the second gas outlet (C5);

4) hydrocracking the tail oil fraction and the circulating hydrogen in the hydrocracking reactor (D) to produce hydrocracking products; hydroisomerizing the diesel fraction and the renewal hydrogen in the hydroisomerization reactor (E)

to produce hydroisomerization products;

5) discharging the hydrocracking products through the hydrocracking product outlet (D1); discharging the hydroisomerization products through the hydroisomerization product outlet (E1); mixing the hydrocracking products and the hydroisomerization products and allowing a resulting mixture to enter the second rectifying column (F) through the hydrogenation product mixture inlet (F1); rectifying the mixture of the hydrocracking products and the hydroisomerization products to produce cracking oil gas, aviation kerosene, diesel, paraffin, the tail oil fraction and the naphtha fraction in the second rectifying column (F); guiding the aviation kerosene to an aviation kerosene tank through the aviation kerosene outlet (F4), guiding the diesel to a diesel tank through the diesel outlet (F5); guiding the naphtha fraction to a naphtha fraction tank through the naphtha fraction outlet (F3);

when aviation kerosene and diesel are the main products, guiding a mixture of the tail oil fraction and paraffin along the discharge pipe (F6) of the tail oil fraction and paraffin to enter the first mixing chamber (I) via the tail oil fraction inlet (I3) to mix with the circulating hydrogen, and then enter the hydrocracking reactor (D); when paraffin is the main product, discharging the mixture of the tail oil fraction and paraffin through the paraffin outlet (F7); and discharging the produced cracking oil gas through the third gas outlet (F2) of the second rectifying column (F); and

6) mixing and introducing the discharged cracking oil gas in 2), 3) and 5) to the condensation fractionating column (G) via the gas inlet (G1), to yield gas and liquid; discharging the gas via the fourth gas outlet (G2) and then allowing the gas to enter the hydrofining reactor (A) via the raw material inlet (A1) for cyclic utilization; and discharging the liquid via the liquid outlet (G3) and then converging the liquid with the naphtha fraction to yield ethylene pyrolysis materials.

3. The method of claim 2, **characterized in that** the Fischer-Tropsch synthetic oil

used in 1) comprises the low-temperature Fischer-Tropsch synthetic oil, or high-temperature Fischer-Tropsch synthetic oil, or part and/or full-range distillates of the oil mixture of the low-temperature Fischer-Tropsch synthetic oil and high-temperature Fischer-Tropsch synthetic oil.

4. The method of claim 2, **characterized in that** in 1), reaction conditions in the hydrofining reactor (A) are as follows: a reaction temperature ranges between 260℃ and 400℃; a reaction pressure ranges between 2.0 MPa and 20.0 MPa; a liquid hourly space velocity ranges between 0.5 h⁻¹ and 3.0 h⁻¹; and a volume ratio of hydrogen to oil ranges between 500: 1 and 2000: 1.
5. The method of claim 2, **characterized in that** in 4), reaction conditions in the hydroisomerization reactor (E) are as follows: a reaction temperature ranges between 280℃ and 400℃; a reaction pressure ranges between 4.0 MPa and 15.0 MPa; a liquid hourly space velocity ranges between 0.5 h⁻¹ and 3.0 h⁻¹; and a volume ratio of hydrogen to oil ranges between 500: 1 and 2000: 1.
6. The method of claim 2, **characterized in that** in 4), reaction conditions in the hydrocracking reactor (D) are as follows: a reaction temperature ranges between 280℃ and 450℃; a reaction pressure ranges between 5.0 MPa and 20.0 MPa; a liquid hourly space velocity ranges between 0.5 h⁻¹ and 3.0 h⁻¹; and a volume ratio of hydrogen to oil ranges between 500: 1 and 2000: 1.
7. The method of claim 4, **characterized in that** in 1), the reaction conditions in the hydrofining reactor (A) are as follows: the reaction temperature ranges between 280℃ and 390℃; the reaction pressure ranges between 4.0 MPa and 15.0 MPa; the liquid hourly space velocity ranges between 0.5 h⁻¹ and 2.0 h⁻¹; and the volume ratio of hydrogen to oil ranges between 500: 1 and 1500: 1.
8. The method of claim 5, **characterized in that** in 4), the reaction conditions in the

hydroisomerization reactor (E) are as follows: the reaction temperature ranges between 280° and 370°; the reaction pressure ranges between 5.0 MPa and 12.0 MPa; the liquid hourly space velocity ranges between 0.5 h⁻¹ and 2.0 h⁻¹; and the volume ratio of hydrogen to oil ranges between 500: 1 and 1500: 1.

9. The method of claim 6, **characterized in that** the in 4), reaction conditions in the hydrocracking reactor (D) are as follows: the reaction temperature ranges between 320° and 400°; the reaction pressure ranges between 5.0 MPa and 15.0 MPa; the liquid hourly space velocity ranges between 0.5 h⁻¹ and 2.0 h⁻¹; and the volume ratio of hydrogen to oil ranges between 700: 1 and 1500: 1.