

PROCESS AND SYSTEM FOR MANUFACTURING LOW-SULFUR RESIDUAL MARINE FUEL OIL

Technical Field

The present invention relates to a process and a system for manufacturing a low-sulfur residual marine fuel oil, which pertains to the field of petroleum refining technology.

Background

Marine fuel oil is the primary power source for ocean-going ships. It mainly includes light diesel, heavy diesel, fuel oil, and residual fuel oil, particularly including: 0# diesel, -10# diesel, 20# heavy diesel, 4# fuel oil, 120# fuel oil, 180# fuel oil and 380# fuel oil, etc. Various ships need different grades of fuel as the ship tonnage varies. In recent years, with increasing environmental protection requirements and decreasing demand for road fuels, the global fuel oil consumption has generally declined. However, driven by the continuous growth of global maritime trade, the demand for marine fuel oil has been strong.

Marine fuel oil is classified into distillate-type and a residue-type based on its quality. After 2015, it is normally required for a distillate marine fuel oil to have a sulfur content of no more than 0.1%. The corresponding requirements can be met by hydrodesulfurization of blending components, the technical route is relatively mature, and therefore the above requirement has little impact on future distillate marine fuel oil. However, for residual marine fuel oil, in order to meet the requirement of the sulfur content of no more than 0.5%, major adjustments need to be made to the manufacturing process. Even for a straight-run residue of a low-sulfur crude oil, it is difficult to achieve a sulfur content of no more than 0.5%, and a qualified marine fuel oil can only be produced after a desulfurization treatment. However, the one-time investment and processing cost of the traditional residual oil hydrogenation apparatus is relatively expensive, leading to rising manufacturing costs.

In order to reduce the burden on the transportation industry, efforts are continuously

made to reduce the cost of marine fuel oil in the fuel supply chain. Thus, the production methods mainly include two routes: raw material optimization, and component upgrading and product blending. The primary raw materials for production include low-value components such as vacuum residue, catalytic slurry, coking wax oil, and ethylene tar. In order to adjust indicators such as viscosity and pour point, it is also necessary to add high-value components such as catalytic diesel and coking diesel in various proportions. Major oil companies around the world are studying low-sulfur marine fuel oil manufacturing technology, and some hydroconversion and upgrading techniques can realize low-sulfur marine fuel oil (marine fuel) production. Nevertheless, due to economic considerations, multi-component blending has always been the most important means for the production of low-sulfur marine fuel. The traditional production method of marine fuel oil is a tank-type batch blending, where cleanness and compatibility of the marine fuel oil produced by blending need to be taken into strong consideration, and the selection and matching of blending components is the key to the production of qualified fuel oil. A residual marine fuel oil mixed with non-petroleum-based raw materials can meet the requirements of the national standard for marine fuel oil in terms of indicators, but there may be problems in practical use such as blockage of the fuel supply system, wear of the high-pressure fuel pumps and nozzles, and poor combustion performance.

Typical oil blending processes include oil tank batch blending and pipeline continuous blending. The tank-type batch blending is prevalent in domestic marine fuel oil blending, with a quantitative production in a single run, and the components to be blended are mixed in the specified blending ratio through pump circulation, electric stirring and the like, and operated intermittently. This is advantageous in that the operation is simple and not affected by the fluctuation of the quality of the component oil, but there are deficiencies including large number of component tanks, long blending period, tendency to oxidation, inaccurate proportion and the like, and the stability of the oil product needs to be improved. Another oil blending process is a pipeline continuous blending. Static mixers are mostly used as the mixing unit in the pipeline continuous blending, and mixing is achieved by changing the fluid flow direction through various members in the pipeline. Chinese patent CN201969532U discloses a marine fuel oil blending device. The technical solution thereof is as follows: light and heavy blending components are sequentially fed into a static mixer and a colloid mill through valves, pipelines, and flow meters respectively, in order to achieve

mixing of the components and refinement of colloids. However, it is difficult to achieve uniform mixing of the light and heavy components with distinctively different densities and viscosities. Phase separation tends to occur in the oil product. When the oil product is refined after entering the colloid mill, although the colloid particles become smaller, it is difficult to achieve uniform mixing, and a colloid mill having high power and energy consumption is used. Chinese patent CN206325416U discloses a residual marine fuel oil blending device. The technical solution thereof is as follows: heavy oil, reflux blended oil, and light oil are connected through component oil tanks, three sets of static mixers and shear mixing units to achieve a gradual decreasing in viscosity of the mixed oil, which, to a certain extent, avoids the problem of uneven local mixing due to substantial difference in the viscosity and density of the mixed oil.

In addition to the limitation of the sulfur content, there are also specifications for marine fuel oil in indicators such as kinematic viscosity, density, cetane index, carbon aromaticity index (CCAI), flash point, hydrogen sulfide, acid value, total sediment, oxidation stability, residual carbon, cold filtration point, cloud point, pour point, appearance, moisture, ash content, vanadium, sodium, aluminum+silicon, net heat value, lubricity, lubricating oil used, and different grades of fuel oil have different requirements for each indicator.

Kinematic viscosity is the primary basis for fuel oil classification, and density may be used as the basis for fuel oil quality. Generally, for the blending manufacturing process of marine fuel oil, three indicators including the density, the kinematic viscosity, and the sulfur content are firstly considered. Flash point is an effective indicator for evaluating the risk of fuel oil ignition, and the flash point of light fractions would directly affect the flash point of blended fuel oil products. The presence of moisture will reduce the heat value of fuel oil and affect the combustion performance of the fuel machinery. Ash content refers to the inorganic substance obtained by calcination after fuel oil is carbonized under specified conditions, and it affects the heat transfer efficiency. Aluminum+silicon mainly derives from the catalyst powder remaining in the residual oil, and may wear the combustion equipment. Indicators such as the ash content and aluminum+silicon limit the use of low-value blending components such as catalytic slurry. High sodium and vanadium contents may lead to "hot corrosion" and damage the parts of the oil extraction unit and increase the total ash content, resulting in deposition problems.

Catalytic slurry and coking wax oil are generally characterized by low sulfur and low cost, but they often have solid contents which affects the performance of the blended product. Chinese patent CN203007222U discloses a process and a device for producing marine fuel oil by using catalytic slurry. Catalytic cracking slurry from the bottom of a catalytic cracking fractionation tower is distilled by a vacuum fractionation tower and separated into two fractions, the light slurry at the top of the tower and the topping slurry at the bottom of the tower. The light slurry is pumped into a dehydration storage tank, and the light slurry is marketed as residual marine fuel oil that meets the national standards; alternatively, dehydrated light oil slurry is drawn out by a pump and mixed with a blending component in the pipeline, and then enters a blending storage tank through a Venturi mixer and is blended with diesel to produce a distillate marine fuel oil that meets the requirements of the national standards, or blended with a residual oil to produce a residual marine fuel oil that meets the requirements of the national standards. Chinese patent CN106753611A discloses a marine fuel oil and manufacturing process and device thereof, wherein catalytic slurry, catalytic diesel, vacuum residue, shale oil, coal tar, methanol, ethanol, and auxiliaries are blended in a certain proportion to produce a qualified 180# product. The use of the low-value raw materials minimizes the production cost, and various blending components can be flexibly substituted to cope with raw material price fluctuations. The device adopts a vertical configuration in which the upper part is a mixing kettle with heating function and the lower part is connected to an electrostatic separation device. A three-electrode electrostatic separation is used to purify the raw materials to increase the additional amount of the low-value catalytic slurry, which reduces the production cost and improves the utilization of the internal space of the device.

Oil blending technology is relatively well established in the field of refined oil. Because the source of refined oil blending raw materials is relatively stable, the optimal blending ratio can be solved within the feasible range defined by a prediction model of known indicators. For a marine fuel oil, the relevant technology is not well established, and there are a wide variety of blending raw materials, mainly low-value and inferior oil products, with large fluctuations in properties and prices. The properties of different batches of the same oil may also remarkably vary, and it is difficult to obtain uniform and stable products by blending. Heavy blending components such as vacuum residue and asphalt have high viscosity and high pour point, and the pour point and viscosity of heavy blending components can be lowered

by means of upgrading, the formulation of the blending components can be optimized, and the amount of the light blending components used may be reduced, so as to form a more economic formulation for production. Chinese patent CN202530048U discloses a hydrogen donor thermal cracking device for an inferior heavy oil, which realizes low-cost upgrading, reduces the viscosity of super heavy oil, and improves API°. Chinese patent CN106883873A discloses a method for upgrading and viscosity reduction of an inferior heavy oil. This method can maximize the production amount of the low-viscosity upgraded crude oil, which meets the requirements in storage and pipeline transportation and has a low investment cost while ensuring the stability of the upgraded oil.

Upon analysis of the prior art, qualified low-sulfur marine fuel products can be directly produced by the hydrocracking technology, but huge one-time investment and high operating cost are required. Other production technologies need at least two stages in which heavy component upgrading is first carried out, followed by tank or pipeline blending, and the production procedure is lengthy, while the blended product has poor uniformity and stability.

Therefore, it has become an urgent technical problem to be solved in the related field to provide new process and system for manufacturing a low-sulfur residual marine fuel oil that can reduce production cost while improving the stability of the resultant product.

Summary of Invention

In order to overcome the above-mentioned defects and deficiencies, an object of the present invention is to provide a process for manufacturing a low-sulfur residual marine fuel oil.

Another object of the present invention is to provide a system for manufacturing a low-sulfur residual marine fuel oil.

In order to achieve the above objects, in one aspect, the present invention provides a process for manufacturing a low-sulfur residual marine fuel oil, comprising:

producing high-temperature upgraded oil-gas upon chemical upgrading of low-quality heavy component, reacting the high-temperature upgraded oil-gas by

contacting and mixing with a blending component under high temperature conditions, homogenizing and stabilizing the mixture resulted from the reaction, and then separating the light component from the mixture, thereby obtaining the low-sulfur residual marine fuel oil.

In a specific embodiment of the above-mentioned process of the present invention, the process further comprises further adding the blending component to the mixture after the light component is separated, so as to improve the yield of the low-sulfur marine fuel oil.

In a specific embodiment of the above-mentioned process of the present invention, the process further comprises adding an auxiliary agent into the blending component, so as to further improve the quality of the low-sulfur marine fuel oil.

In the present invention, the auxiliary agent includes a compounded auxiliary agent composed of one or more of alkyl-substituted benzene, alcohol, amine, phenol, sulfonic acid, phenol, amide-based compound and derivatives thereof.

In a specific embodiment of the above-mentioned process of the present invention, the low-quality heavy component include one or more of secondary processing products in the refining chemical industry such as residual oil, catalytic slurry, coking wax oil, ethylene tar, and deoiled asphalt.

Herein, the residual oil includes atmospheric residual oil, vacuum residual oil and a mixture thereof.

In a specific embodiment of the above-mentioned process of the present invention, the chemical upgrading includes one or more of visbreaking, hydrogen donor thermal cracking, hydrogen presence thermal cracking, fluidized thermal conversion, delayed coking, and heavy oil hydroconversion.

The visbreaking, hydrogen donor thermal cracking, hydrogen presence thermal cracking, fluidized thermal conversion, delayed coking, and heavy oil hydroconversion processes used in the present invention are all conventional processes, and those skilled in the art can reasonably set up the process parameters used in these processes as practically needed in field operations, as long as the achievement of the objects of the present invention is ensured.

In a specific embodiment of the above-mentioned process of the present invention,

the heavy oil hydroconversion comprises one or more of fixed bed, suspended bed, boiling bed, and moving bed heavy oil hydrogenation processes.

The fixed bed, suspended bed, boiling bed, and moving bed heavy oil hydrogenation processes used in the present invention are all conventional processes, and those skilled in the art can reasonably set up the process parameters used in these processes as practically needed in field operations, as long as the achievement of the objects of the present invention is ensured.

In a specific embodiment of the above-mentioned process of the present invention, the fluidized thermal conversion comprises one or more of fluidized coking, flexicoking, fluidized catalytic cracking, and circulating fluidized bed processes.

The fluidized coking, flexicoking, fluidized catalytic cracking, and circulating fluidized bed processes used in the present invention are all conventional processes, and those skilled in the art can reasonably set up the process parameters used in these processes as practically needed in field operations, as long as the achievement of the objects of the present invention is ensured.

In a specific embodiment of the above-mentioned process of the present invention, the high-temperature upgraded oil-gas is a gas-liquid mixture at a temperature of 360°C or higher.

In the present invention, the high-temperature upgraded oil-gas at the oil-gas outlet of the chemical upgrading unit is a gas-liquid mixture at a temperature of 360°C or more. In the existing conventional processes in the field, this portion of oil-gas is fed into a fractionation unit after heat exchange or cooling, and a part of the separated fraction is transported to the tank section, and is blended with other components in the product formulation to produce a qualified product. Due to distinctively different properties, the mixture mass transfer efficiency is poor.

In a specific embodiment of the above-mentioned process of the present invention, the blending component includes one or more of catalytic diesel, catalytic slurry, hydrotreated residual oil, coking diesel, coking wax oil, ethylene tar, and straight-run diesel.

In a specific embodiment of the above-mentioned process of the present invention, the amount of the blending component used is 3 to 100% of the mass of the high-

temperature upgraded oil-gas.

In a specific embodiment of the above-mentioned process of the present invention, the reaction temperature of the reaction is 80°C or higher;

Preferably, the reaction temperature of the reaction is 120°C or higher.

In a specific embodiment of the above-mentioned process of the present invention, the blending component is injected at one or more positions of the oil-gas outlet of the chemical upgrading unit used for chemical upgrading, the inlet of the homogenization and stabilization unit used for homogenization and stabilization, and the oil-gas transportation pipeline connecting the oil-gas outlet and the inlet of the homogenization and stabilization unit, and the high-temperature upgraded oil-gas is reacted by contacting and mixing with the blending component under high temperature conditions.

In a specific embodiment of the above-mentioned process of the present invention, the low-sulfur residual marine fuel oil has a sulfur content of less than 0.5%, and a kinematic viscosity at 50°C of less than 500 mm²/s. Unless otherwise specified, the sulfur content in the present invention is a percentage by weight, and the kinematic viscosity is a kinematic viscosity at 50°C.

In the present invention, the high-temperature upgraded oil-gas is produced by chemical upgrading of low-quality heavy component, wherein the chemical upgrading includes targeted upgrading of the low-quality heavy components in terms of indicators such as sulfur content, acid value, viscosity, and pour point, so as to meet or approach the quality standard for the product.

In a specific embodiment of the above-mentioned process of the present invention, the process further includes a pre-treatment operation of the low-quality heavy component raw materials, and the pre-treatment includes dehydration, desolidification and purification treatment, and the like.

In the present invention, the mixture obtained after the high-temperature upgraded oil-gas is reacted by contacting and mixing with the blending component under high temperature conditions contains a light component, and the light component may lead to safety issues in storage, transportation, and usage of the resultant low-sulfur residual marine fuel oil product. Therefore, in the present invention, the light

component needs to be separated from the mixture in a homogenization and stabilization unit to ensure that the flash point exceeds 60°C, so as to obtain a qualified, uniform and stable low-sulfur marine fuel oil.

In another aspect, the present invention also provides a system for manufacturing a low-sulfur residual marine fuel oil, including:

a chemical upgrading unit, a homogenization and stabilization unit and/or a product storage tank, wherein at least one injection port is provided between the oil-gas outlet of the chemical upgrading unit and the inlet of the homogenization and stabilization unit, the injection port being used for injecting a blending component and reacting the high-temperature upgraded oil-gas by contacting and mixing with the blending component, and the mixture resulted from the reaction being fed through an oil-gas transportation pipeline into the homogenization and stabilization unit or the product storage tank;

and/or a mixing segment is provided in an oil-gas transportation pipeline between the oil-gas outlet of the chemical upgrading unit and the inlet of the homogenization and stabilization unit, wherein the high-temperature upgraded oil-gas is reacted by the contacting and mixing with the blending component in the mixing segment, and the resultant mixture is fed through the oil-gas transportation pipeline into the homogenization and stabilization unit or the product storage tank;

when the system includes the chemical upgrading unit, the homogenization and stabilization unit, and the product storage tank, the outlet of the homogenization and stabilization unit is connected to the inlet of the product storage tank through an oil-gas transportation pipeline.

In a specific embodiment of the above-mentioned system of the present invention, when the system includes the chemical upgrading unit, the homogenization and stabilization unit, and the product storage tank, at least one injection port is provided between the outlet of the homogenization and stabilization unit and the inlet of the product storage tank, and the injection port is used for injecting a blending component;

and/or a mixing segment is provided in the oil-gas transportation pipeline between the outlet of the homogenization and stabilization unit and the inlet of the product storage tank.

In a specific embodiment of the above-mentioned system of the present invention, the homogenization and stabilization unit includes one or more of a fractionation tower, a flash tower, and a degassing tank.

In a specific embodiment of the above-mentioned system of the present invention, the chemical upgrading unit comprises one or more of a visbreaking reactor, a hydrogen donor thermal cracking reactor, a hydrogen presence thermal cracking reactor, a fluidized thermal conversion reactor, a delayed coking reactor, and a heavy oil hydroconversion reactor.

The visbreaking reactor, the hydrogen donor thermal cracking reactor, the hydrogen presence thermal cracking reactor, the fluidized thermal conversion reactor, the delayed coking reactor, and the heavy oil hydroconversion reactor used in the present invention are all conventional devices, and those skilled in the art can reasonably choose any commercially available or self-built devices as practically needed in field operations, as long as the achievement of the objects of the present invention is ensured.

In a specific embodiment of the above-mentioned system of the present invention, the heavy oil hydroconversion reactor includes one or more of a fixed bed heavy oil hydroconversion reactor, a suspended bed heavy oil hydroconversion reactor, a boiling bed heavy oil hydroconversion reactor, and a moving bed heavy oil hydroconversion reactor.

The fixed bed heavy oil hydroconversion reactor, the suspended bed heavy oil hydroconversion reactor, the boiling bed heavy oil hydroconversion reactor, and the moving bed heavy oil hydroconversion reactor used in the present invention are all conventional devices, and those skilled in the art can reasonably choose any commercially available or self-built devices as practically needed in field operations, as long as the achievement of the objects of the present invention is ensured.

In a specific embodiment of the above-mentioned system of the present invention, the fluidized thermal conversion reactor includes one or more of a fluidized coking reactor, a flexicoking reactor, a fluidized catalytic cracking reactor, and a circulating fluidized bed reactor.

The fluidized coking reactor, the flexicoking reactor, the fluidized catalytic cracking reactor, and the circulating fluidized bed reactor used in the present invention are all

conventional devices, and those skilled in the art can reasonably choose any commercially available or self-built devices as practically needed in field operations, as long as the achievement of the objects of the present invention is ensured.

In a specific embodiment of the above-mentioned system of the present invention, the system further includes a pre-treatment unit for the pre-treatment of low-quality and inferior heavy component raw materials, and the pre-treatment unit includes a dehydration unit, a desolidification and purification treatment unit, and the like.

The present invention provides a process and a system for manufacturing a low-sulfur residual marine fuel oil through upgrading of heavy component coupled with in-situ blending, specifically including: producing high-temperature upgraded oil-gas by chemical upgrading of low-quality heavy components, reacting the high-temperature upgraded oil-gas by contacting and mixing with a blending component under high temperature conditions, homogenizing and stabilizing the mixture resulted from the reaction, and then separating the light component from the mixture, thereby obtaining the low-sulfur residual marine fuel oil. The process provided by the invention has a simple procedure, low energy consumption, and the uniformity and stability of the resultant low-sulfur marine fuel oil product are greatly improved.

Brief Description of the Drawings

In order to better describe the examples of the present invention or the technical solutions in the prior art, the drawings necessary for the description of the examples will be briefly described in the following. Obviously, the drawings described below are certain examples of the present invention, and it is possible for those of ordinary skill in the art to attain other drawings based on these drawings without inventive work.

Fig. 1 is a schematic illustration of the degree of phase separation of the RMG380# low-sulfur marine fuel oil provided in Example 1 of the present invention after being left standing and stored for 30 days.

Fig. 2 is a schematic illustration of the degree of phase separation of the RMG380# low-sulfur marine fuel oil provided in Comparative Example 1 after being left standing and stored for 21 days.

Detailed Description of Invention

In order to better understand the technical features, objectives, and beneficial effects of the present invention, the technical solutions of the present invention will now be described in details below with reference to the following specific examples, which should not be construed as a limitation to the implemental scope of the present invention.

System Examples

Example 1-1

This example provides a system for manufacturing a low-sulfur residual marine fuel oil, including a visbreaking reactor, a fractionation tower, and a product storage tank, wherein an injection port for quenching oil is provided at the oil-gas outlet of the visbreaking reactor. The injection port for quenching oil is used for injecting a blending component and reacting the high-temperature upgraded oil-gas from the oil-gas outlet of the visbreaking reactor by contacting and mixing with the blending component, and the mixture resulted from the reaction is fed through an oil-gas transportation pipeline into the fractionation tower.

The outlet of the fractionation tower is connected to the inlet of the product storage tank via the oil-gas transportation pipeline.

Example 2-2

This example provides a system for manufacturing a low-sulfur residual marine fuel oil, including a hydrogen presence thermal cracking reactor, a fractionation tower, and a product storage tank, wherein an injection port for quenching oil is provided at the oil-gas outlet of the hydrogen presence thermal cracking reactor. The injection port for quenching oil is used for injecting a blending component and reacting the high-temperature upgraded oil-gas from the oil-gas outlet of the hydrogen presence thermal cracking reactor by contacting and mixing with the blending component, and the mixture resulted from the reaction is fed through an oil-gas transportation pipeline into the fractionation tower.

The outlet of the fractionation tower is connected to the inlet of the product storage tank via the oil-gas transportation pipeline.

Example 3-3

This example provides a system for manufacturing a low-sulfur residual marine fuel oil, including a circulating fluidized bed reactor, a fractionation tower, and a product storage tank, wherein an injection port for quenching oil is provided at the oil-gas outlet of the circulating fluidized bed reactor. The injection port for quenching oil is used for injecting a blending component and reacting the high-temperature upgraded oil-gas from the oil-gas outlet of the circulating fluidized bed reactor by contacting and mixing with the blending component, and the mixture resulted from the reaction is fed through an oil-gas transportation pipeline into the fractionation tower.

The outlet of the fractionation tower is connected to the inlet of the product storage tank via the oil-gas transportation pipeline.

Example 4-4

This example provides a manufacturing system of a low-sulfur residual marine fuel oil, including a delayed coking reactor, a fractionation tower, and a product storage tank, wherein an injection port for quenching oil is provided at the oil-gas outlet of the delayed coking reactor. The injection port for quenching oil is used for injecting a blending component and reacting the high-temperature upgraded oil-gas from the oil-gas outlet of the delayed coking reactor by contacting and mixing with the blending component, and the mixture resulted from the reaction is fed through an oil-gas transportation pipeline into the fractionation tower.

The outlet of the fractionation tower is connected to the inlet of the product storage tank via the oil-gas transportation pipeline.

Example 5-5

This example provides a system for manufacturing a low-sulfur residual marine fuel oil, including a visbreaking reactor, a heavy oil hydroconversion reactor, a fractionation tower, and a product storage tank, wherein the visbreaking reactor is connected to the heavy oil hydroconversion reactor via a pipeline and an injection port for quenching oil is provided at the oil-gas outlet of the heavy oil hydroconversion reactor. The injection port for quenching oil is used for injecting a blending component and reacting the high-temperature upgraded oil-gas from the oil-gas outlet of the heavy oil hydroconversion reactor by contacting and mixing with the blending component, and

the mixture resulted from the reaction is fed through an oil-gas transportation pipeline into the fractionation tower.

The outlet of the fractionation tower is connected to the inlet of the product storage tank via the oil-gas transportation pipeline.

Example 6-6

This example provides a system for manufacturing a low-sulfur residual marine fuel oil, including a fluidized thermal conversion reactor, a fractionation tower, and a product storage tank, wherein a mixing segment is provided in the oil-gas transportation pipeline between the outlet of the fluidized thermal conversion reactor and the fractionation tower. The high-temperature upgraded oil-gas is reacted by the contacting and mixing with a blending component in the mixing segment, and the mixture resulted from the reaction is fed through an oil-gas transportation pipeline into the fractionation tower.

The outlet of the fractionation tower is connected to the inlet of the product storage tank via the oil-gas transportation pipeline, and a mixing segment is also provided in the oil-gas transportation pipeline between the outlet of the fractionation tower and the inlet of the product storage tank.

Process Examples

Example 1

This example provides a process for manufacturing a low-sulfur residual marine fuel oil, which is implemented by using the system for manufacturing a low-sulfur residual marine fuel oil provided in Example 1-1, and includes the following steps.

A vacuum residue having a sulfur content of 0.82% and a kinematic viscosity of 68200mm²/s was added into a visbreaking reactor, and after 30 minutes of reaction at a temperature of 425°C, a high-temperature upgraded oil-gas at a temperature of 416°C was produced. A catalytic diesel having a kinematic viscosity of 5 mm²/s and a sulfur content of 0.10% was injected into the injection port for quenching oil at the oil-gas outlet on the top of the visbreaking reactor, in an amount of 12% of the mass of the high-temperature upgraded oil-gas. The high-temperature upgraded oil-gas was brought into contact and mixed with the catalytic diesel for a stabilization reaction at

360°C. The mixture resulted from the reaction was fed into a fractionation tower for homogenization and stabilization, a light component of 1.5 m% of the oil-gas was separated from the top of the tower (m% represents mass percentage in the present disclosure), and a qualified (kinematic viscosity at 50°C: 355 mm²/s, sulfur content: 0.49%) RMG380# low-sulfur residual marine fuel oil was directly obtained at the bottom of the tower.

The properties of the RMG380# low-sulfur residual marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade I after the evaluation. In addition, the RMG380# low-sulfur residual marine fuel oil was left standing and stored for 30 days with no phase separation, as shown in Fig. 1.

Example 2

This example provides a process for manufacturing a low-sulfur residual marine fuel oil, which is implemented by using the system for manufacturing a low-sulfur residual marine fuel oil provided in Example 2-2, and includes the following steps.

A heavy fuel oil having a sulfur content of 1.65% and a kinematic viscosity of 485mm²/s was added into a hydrogen presence thermal cracking reactor, and after 25 minutes of desulfurization reaction under the condition of 405°C and 3.5 MPa, a high-temperature upgraded oil-gas at a temperature of 390°C was produced. A catalytic slurry having a kinematic viscosity of 185 mm²/s and a sulfur content of 0.25% was injected into the injection port for quenching oil at the oil-gas outlet on the top of the hydrogen presence thermal cracking reactor, in an amount of 25% of the mass of the high-temperature upgraded oil-gas. The high-temperature upgraded oil-gas was brought into contact and mixed with the catalytic slurry for a stabilization reaction at 350°C. The mixture resulted from the reaction was fed into a fractionation tower for homogenization and stabilization, a light component of 1 m% of the oil-gas was separated from the top of the tower, and a qualified (kinematic viscosity at 50°C: 167 mm²/s, sulfur content: 0.46%, flash point: 62°C) RMG180# low-sulfur residual marine fuel oil was directly obtained at the bottom of the tower.

The properties of the RMG180# low-sulfur residual marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade I after the evaluation.

Example 3

This example provides a process for manufacturing a low-sulfur residual marine fuel oil, which is implemented by using the system for manufacturing a low-sulfur residual marine fuel oil provided in Example 3-3, and includes the following steps.

An atmospheric residue having a sulfur content of 1.05%, a kinematic viscosity of 4395mm²/s and an acid value of 4.4 mg KOH/g was added into a circulating fluidized bed reactor, and after an upgrading reaction with a waste FCC catalyst under the conditions of 485°C and a reaction duration of 5 s, a high-temperature upgraded oil-gas at a temperature of 480°C was produced. A mixture of coking wax oil and coking diesel having a kinematic viscosity of 15 mm²/s and a sulfur content of 0.15% was injected into the injection port for quenching oil at the oil-gas outlet on the top of the circulating fluidized bed reactor, in an amount of 17% of the mass of the high-temperature upgraded oil-gas. The high-temperature upgraded oil-gas was brought into contact and mixed with the mixture of coking wax oil and coking diesel for a stabilization reaction at 405°C. The mixture resulted from the reaction was fed into a fractionation tower for homogenization and stabilization, a gasoline fraction of 8 m% of the oil-gas was separated from the top of the tower, and a qualified (kinematic viscosity at 50°C: 367 mm²/s, sulfur content: 0.48%) RMG380# low-sulfur residual marine fuel oil was directly obtained at the bottom of the tower.

The properties of the RMG380# low-sulfur residual marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade I after the evaluation.

Example 4

This example provides a process for manufacturing a low-sulfur residual marine fuel oil, which is implemented by using the system for manufacturing a low-sulfur residual marine fuel oil provided in Example 4-4, and includes the following steps.

A deoiled asphalt having a sulfur content of 1.05%, a kinematic viscosity of 664395mm²/s and an acid value of 2.4 mg KOH/g was added into a delayed coking reactor, and after an upgrading reaction under the reaction conditions of 505°C, 0.15 MPa and zero circulation ratio, a high-temperature upgraded oil-gas at a temperature of 498°C was produced. A mixture of ethylene tar and catalytic diesel having a kinematic viscosity of 15 mm²/s and a sulfur content of 0.15% was injected into the

injection port for quenching oil at the oil-gas outlet on the top of the delayed coking reactor, in an amount of 30% of the mass of the high-temperature upgraded oil-gas. The high-temperature upgraded oil-gas was brought into contact and mixed with the mixture of ethylene tar and catalytic diesel for a stabilization reaction at 395°C. The mixture resulted from the reaction was fed into a fractionation tower for homogenization and stabilization, a light coke gasoline of 5 m% of the oil-gas was separated from the top of the tower, and a qualified (kinematic viscosity at 50°C: 357 mm²/s, sulfur content: 0.49%) RMG380# low-sulfur residual marine fuel oil was directly obtained at the bottom of the tower.

The properties of the RMG380# low-sulfur residual marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade I after the evaluation.

Example 5

This example provides a process for manufacturing a low-sulfur residual marine fuel oil, which is implemented by using the system for manufacturing a low-sulfur residual marine fuel oil provided in Example 5-5, and includes the following steps.

A deoiled asphalt having a sulfur content of 1.05%, a kinematic viscosity of 664395mm²/s and an acid value of 2.4 mg KOH/g was added into a visbreaking reactor together with a catalytic slurry, and was upgraded under the reaction conditions of 408°C and 0.6 MPa; then, it entered a heavy oil hydroconversion reactor for desulfurization under the conditions of 385°C and 5.0 MPa, to produce a high-temperature upgraded oil-gas at a temperature of 381°C. A mixture of ethylene tar and catalytic diesel had a kinematic viscosity of 15 mm²/s and a sulfur content of 0.15% was injected into the injection port for quenching oil at the oil-gas outlet on the top of the heavy oil hydroconversion unit, in an amount of 60% of the mass of the high-temperature upgraded oil-gas. The high-temperature upgraded oil-gas was brought into contact and mixed with the mixture of ethylene tar and catalytic diesel for a stabilization reaction at 345°C. The mixture resulted from the reaction was fed into a fractionation tower for homogenization and stabilization, a light component of 1.8 m% of the oil-gas was separated from the top of the tower, and a qualified (kinematic viscosity at 50°C: 346 mm²/s, sulfur content: 0.49%) RMG380# low-sulfur residual marine fuel oil was directly obtained at the bottom of the tower.

The properties of the RMG380# low-sulfur residual marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade I after the evaluation.

Example 6

This example provides a process for manufacturing a low-sulfur residual marine fuel oil, which is implemented by using the system for manufacturing a low-sulfur residual marine fuel oil provided in Example 6-6, and includes the following steps.

An atmospheric residue having a sulfur content of 1.05%, a kinematic viscosity of 4395mm²/s and an acid value of 4.4 mg KOH/g was added into a fluidized thermal conversion reactor, and after upgrading reaction under the reaction conditions of 425°C and 15 min, a high-temperature upgraded oil-gas at a temperature of 410°C was produced. A mixture of coking diesel and ethylene tar with dissolved polyisobutylene succinimidyl phenylboronic acid stabilizing aid, having a kinematic viscosity of 15 mm²/s and a sulfur content of 0.15%, was injected into a mixing segment provided in the pipeline at the oil-gas outlet of the fluidized thermal conversion reactor, in an amount of 18% of the mass of the high-temperature upgraded oil-gas. The high-temperature upgraded oil-gas was brought into contact and mixed with the mixture of coking diesel and ethylene tar with the dissolved stabilizing aid for a stabilization reaction at 397°C. The mixture resulted from the reaction was fed into a fractionation tower for homogenization and stabilization, a light component of 2 m% of the oil-gas was separated from the top of the tower, and a qualified (kinematic viscosity at 50°C: 367 mm²/s, sulfur content: 0.48%) RMG380# low-sulfur residual marine fuel oil was directly obtained at the bottom of the tower.

The properties of the RMG380# low-sulfur residual marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade I after the evaluation.

A coking diesel was added into a part of the RMG380# low-sulfur residual marine fuel oil in a mixing segment provided in the oil-gas transportation pipeline between the outlet of the fractionation tower and the inlet of the product storage tank, in an amount of 5% of the mass of the part of the RMG380# low-sulfur residual marine fuel oil, to obtain a qualified (kinematic viscosity at 50°C: 163 mm²/s, sulfur content: 0.45%, flash point: 62°C) RMG180# low-sulfur marine fuel oil.

Comparative Example 1

This comparative example provides a process for manufacturing a low-sulfur marine fuel oil, including the following steps.

A vacuum residue having a sulfur content of 0.82% and a kinematic viscosity of 68200mm²/s was added into a visbreaking reactor, and a high-temperature upgraded oil-gas was produced after 30 minutes of reaction at a temperature of 425°C. The high-temperature upgraded oil-gas was cooled down by heat exchange and then fed into a fractionation tower. A light component was separated at the top of the tower, and the resultant visbroken heavy oil was fed into a storage tank and left standing for 3 days, and then blended with a catalytic diesel having a kinematic viscosity of 5 mm²/s and a sulfur content of 0.10% in an amount of 12% of the mass of the visbroken heavy oil. After blending, an RMG380# low-sulfur marine fuel oil with a kinematic viscosity of 375 mm²/s and a sulfur content of 0.49% was obtained.

The properties of the RMG380# low-sulfur marine fuel oil were evaluated according to ASTM-D2781/D4740, and the product stability thereof was determined as Grade II after the evaluation. In addition, when the RMG380# low-sulfur marine fuel oil was left standing and stored for 21 days, a phase separation occurred, as shown in Fig. 2.

The properties of the RMG380# low-sulfur marine fuel oil after being left standing and stored for 21 days were evaluated, and the product stability thereof was downgraded to Grade III after the evaluation.

Comparative Example 2

This comparative example provides a process for manufacturing a low-sulfur marine fuel oil, including the following steps.

A heavy fuel oil having a sulfur content of 1.65% and a kinematic viscosity of 485mm²/s was added into a hydrogen presence upgrading reactor, and after 25 minutes of desulfurization reaction under the conditions of 405°C and 3.5 MPa, a high-temperature upgraded oil-gas at a temperature of 390°C was produced. The high-temperature upgraded oil-gas was directly blended with a catalytic slurry (having a kinematic viscosity of 185 mm²/s and a sulfur content of 0.25%, used in an amount of 25% of the mass of the high-temperature upgraded oil-gas) to obtain an oil product. The obtained oil product had a kinematic viscosity of 143 mm²/s and a sulfur content

of 0.44%, but had a flash point of 57°C, which did not meet the specification requirement of a flash point higher than 60°C required by the standard for an RMG180# low-sulfur marine fuel oil product.

The above description provides only specific examples of the present invention and cannot limit the implementable scope of the present invention. As such, replacement of equivalent components, or equivalent variation and modification in accordance with the scope of protection of the present patent invention, shall be construed as being encompassed within the scope of the patent. In addition, technical feature(s) and technical feature(s), technical feature(s) and technical invention(s), and technical invention(s) and technical invention(s) of the present invention may be arbitrarily combined and used.

CLAIMS

1. A process for manufacturing a low-sulfur residual marine fuel oil, comprising:

producing high-temperature upgraded oil-gas by chemical upgrading of low-quality heavy component, reacting the high-temperature upgraded oil-gas by contacting and mixing with a blending component under high temperature conditions, homogenizing and stabilizing the mixture resulted from the reaction, and then separating the light component from the mixture, thereby obtaining the low-sulfur residual marine fuel oil; wherein the high-temperature upgraded oil-gas is a gas-liquid mixture at a temperature of 360°C or higher and the reaction temperature of the reaction is 80°C or higher.
2. The process according to claim 1, wherein the process further comprises further adding the blending component to the mixture after the light component is separated.
3. The process according to claim 1, wherein the process further comprises adding an auxiliary agent into the blending component to further improve the quality of the low-sulfur marine fuel oil.
4. The process according to any one of claims 1 to 3, wherein the low-quality heavy component includes one or more of residual oil, catalytic slurry, coking wax oil, ethylene tar, and deoiled asphalt.
5. The process according to any one of claims 1 to 3, wherein the chemical upgrading includes one or more of visbreaking, hydrogen donor thermal cracking, hydrogen presence thermal cracking, fluidized thermal conversion, delayed coking, and heavy oil hydroconversion.
6. The process according to claim 5, wherein the heavy oil hydroconversion comprises one or more of fixed bed, suspended bed, boiling bed, and moving bed heavy oil hydrogenation processes.
7. The process according to claim 5, wherein the fluidized thermal conversion comprises one or more of fluidized coking, flexicoking, fluidized catalytic cracking, and circulating fluidized bed processes.
8. The process according to any one of claims 1-3, wherein the blending component includes one or more of catalytic diesel, catalytic slurry, hydrotreated residual oil,

coking diesel, coking wax oil, ethylene tar, and straight-run diesel.

9. The process according to any one of claims 1 to 3, wherein the amount of the blending component used is 3 to 100% of the mass of the high-temperature upgraded oil-gas.

10. The process according to claim 1, wherein the reaction temperature of the reaction is 120°C or higher.

11. The process according to any one of claims 1 to 3, wherein the blending component is injected at one or more positions of the oil-gas outlet of the chemical upgrading unit used for chemical upgrading, the inlet of the homogenization and stabilization unit used for homogenization and stabilization, and the oil-gas transportation pipeline connecting the oil-gas outlet and the inlet of the homogenization and stabilization unit, and the high-temperature upgraded oil-gas is reacted by contacting and mixing with the blending component under high temperature conditions.

12. The process according to any one of claims 1 to 3, wherein the low-sulfur residual marine fuel oil has a sulfur content of less than 0.5%, and a kinematic viscosity of less than 500 mm²/s at 50°C.