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(71) Applicants:
- **China Petroleum & Chemical Corporation**
  Beijing 100728 (CN)
- **Sinopec Dalian Research Institute of Petroleum and Petrochemicals Co., Ltd.**
  Lushunkou District
  Dalian, Liaoning 116045 (CN)

(72) Inventors:
- **GUO, Dan**
  Dalian, Liaoning 116045 (CN)
- **HOU, Shuandi**
  Dalian, Liaoning 116045 (CN)
- **CHU, Renqing**
  Dalian, Liaoning 116045 (CN)
- **WU, Yun**
  Dalian, Liaoning 116045 (CN)
- **GOU, Lianzhong**
  Dalian, Liaoning 116045 (CN)

(74) Representative: **karo IP**
Patentanwälte PartG mbB
Steinstraße 16-18
40212 Düsseldorf (DE)

(54) METHOD AND DEVICE FOR MANUFACTURING NEEDLE COKE USING MIXED FEEDSTOCK OIL

(57) The present invention relates to a method and apparatus for producing the needle coke with a mixed feedstock oil. According to the present invention, a needle coke with excellent mechanical properties can be produced. The method for producing a needle coke according to the present invention comprises the following steps: (1) hydrotreating a mixture of a first feedstock oil and a second feedstock oil to obtain a hydrogenated product;(2) cracking the hydrogenated product to obtain a cracked product; (3) producing the needle coke with the cracked product as a starting material, wherein the first feedstock oil has an aromatic carbon ratio of greater than 65mol%, the second feedstock oil has an aromatic carbon ratio of greater than 60mol%, the first feedstock oil has a coking starting temperature lower than that of the second feedstock oil by 10-140°C.

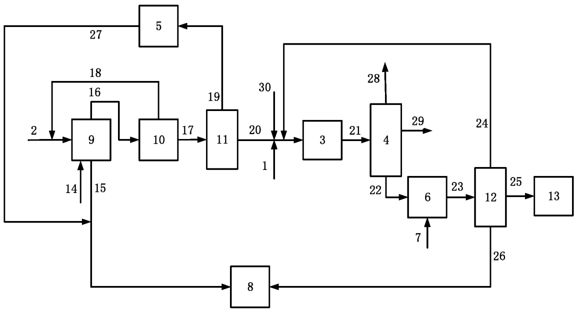

Fig. 1

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Description

Technical Field

[0001] The invention belongs to the technical field of petrochemical industry, and particularly relates to a method and apparatus for producing a needle coke with a mixed feedstock oil.

Background Art

[0002] Aromatic oil is a high-quality starting material for producing needle coke. For example, catalytic slurry oil and ethylene tar are the preferred materials for producing an oilbased needle coke. However, both have certain problems in the actual production process. Catalytic slurry oil needs a solid-removal treatment and a hydrodesulfurization treatment due to its high ash and sulfur contents; while ethylene tar usually needs a colloid-removal treatment due to its high colloid content.

[0003] CN110511785A discloses a method for preparing a starting material for needle coke from a catalytic slurry oil, which method specifically comprises firstly adding a low molecular weight normal alkane to the slurry oil, removing asphaltene to obtain an upper layer liquid, extracting and desolidifying the upper layer liquid to obtain an aromatics-enriched oil, and subjecting the aromatics-enriched oil to the hydrodesulfurization treatment to obtain the starting material for needle coke. The method uses a combined extraction-hydrogenation process to desolidify and desulfurize the catalytic slurry oil so that it meets the requirements for being a starting material for needle coke.

[0004] CN103102974A discloses a method for producing clean fuel oil from ethylene tar, which comprises separating ethylene tar into a light fraction and a heavy fraction, mixing the heavy fraction with a conventional coking starting material, and obtaining a coker gasoline and a coker diesel through delayed coking, wherein the coker gasoline is subjected to hydrogenation refining, and the coker diesel is mixed with the light fraction of ethylene tar and subjected to hydrogenation treatment to obtain clean gasoline and diesel products. The method selects a suitable processing method according to the composition characteristic of the fractions of ethylene tar to improve the yield of light fuel oil.

[0005] When the catalytic slurry oil is hydrodesulfurized, the carbon-carbon double bonds of some aromatic rings are saturated and and converted into alkyl side chains. These aromatic hydrocarbons with alkyl side chains will play a role in hydrogen supply during the production of needle coke, hindering the polymerization of molecules to form macromolecules, resulting in incomplete development of the mesophase and affecting the performance of needle coke products. Ethylene tar contains aromatic olefins, which have poor thermal stability and are easily polycondensed into coke under high temperature conditions, affecting the long-term operation of the coking unit.

Summary of the invention

[0006] In view of the shortcomings of the prior art, the present invention provides a method and apparatus for producing the needle coke with a mixed feedstock oil, which can effectively solve the problem of poor quality of needle coke produced due to hydrogenation treatment of catalytic slurry oil, and the problem of short operation period of delayed coking unit due to poor thermal stability of ethylene tar.

[0007] Specifically, in a first aspect, the present invention relates to a method for producing a needle coke, comprising the following steps:

(1) hydrotreating a mixture of a first feedstock oil and a second feedstock oil to obtain a hydrogenated product;
(2) cracking the hydrogenated product to obtain a cracked product;
(3) using the cracked product as a starting material to produce the needle coke,

wherein the first feedstock oil has an aromatic carbon ratio of greater than 65mol% (preferably 70mol%-95mol%), the second feedstock oil has an aromatic carbon ratio of greater than 60mol% (preferably 70mol%-90mol%), and the first feedstock oil has a coking starting temperature lower than that of the second feedstock oil by 10-140°C, preferably by 35-105°C.

[0008] In addition, in a second aspect, the present invention relates to a apparatus for producing a needle coke, comprising the following units:

a feedstock oil supplying unit, which is configured for providing a first feedstock oil and a second feedstock oil;
a hydrogenation unit, which is configured for hydrotreating a mixture of the first feedstock oil and the second feedstock oil to obtain a hydrogenated product;
a cracking unit, which is configured for cracking the hydrogenated product to obtain a cracked product;
a needle coke production unit, which is configured for producing the needle coke with the cracked product as a starting material,

wherein the aromatic carbon content of the first feedstock oil is greater than 65 mol% (preferably 70 mol%-95 mol%), the aromatic carbon content of the second feedstock oil is greater than 60 mol% (preferably 70 mol%-90 mol%), and the coking starting temperature of the first feedstock oil is 10-140 °C lower than the coking starting temperature of the second feedstock oil, preferably 35-105 °C lower.

Technical Effects

[0009] Compared with the prior art, the method and apparatus for producing a needle coke with a mixed feedstock oil provided by the present invention has one or a combination of all or part of the following advantages:

(1) According to the present invention, in a preferred embodiment, ethylene tar is first subjected to an extraction unit to remove colloid/asphaltene to obtain an aromatics-enriched oil, and the aromatics-enriched oil is then separated into a first lighter oil and a first heavier oil according to the distillation range. The first lighter oil is rich in dicyclic aromatics. The first heavier oil is rich in tricyclic and higher aromatics, and the first heavier oil is a high-quality starting material for producing a needle coke. The condensation product obtained after the condensation reaction of the first lighter oil is mixed with a raffinate phase rich in colloid/asphaltene obtained from the extraction unit to produce a low-sulfur petroleum coke. The addition of the condensation product can improve the dispersion of colloid/asphaltene in the raffinate phase, avoid its precipitation and coking in the heating furnace, and improve the quality and yield of the low-sulfur petroleum coke.

(2) According to the present invention, in a preferred embodiment, the catalytic slurry oil is mixed with the first heavier oil and the mixture is sent to the hydrogenation reaction unit. Since the first heavier oil (derived from ethylene tar) contains aromatic olefins, the carbon-carbon double bonds of olefins are easier to be hydrogenated than the carbon-carbon double bonds of aromatic rings. Therefore, in the hydrogenation reaction unit, the carbon-carbon double bonds of olefins in the first heavier oil are preferentially saturated, followed by the hydrodesulfurization reaction of catalytic slurry oil, and finally the carbon-carbon double bonds of aromatic hydrocarbons are saturated. Due to the existence of the competitive reactions, the aromatic ring saturation rate of the catalytic slurry oil can be effectively reduced, avoiding the production of excessive aromatic hydrocarbons with a large number of alkyl side chains or cycloalkyl side chains, resulting in a decrease in the number of aromatic hydrocarbon rings and affecting the mechanical properties of the needle coke.

(3) According to the present invention, in a preferred embodiment, the hydrogenated tail oil is sent to a cracking reaction unit to break the aromatic side chains saturated during the hydrogenation process, and the molecules are converted back into aromatic structures with short side chains. The separated intermediate distillate oil (containing tricyclic and tetracyclic aromatics fractions) is more suitable as a starting material for producing the needle coke. The second lighter oil is a cracked product rich in small molecular hydrocarbons. If it is returned to the hydrotreating unit, the naphtha yield can be increased. If the second lighter oil is sent to a low-sulfur petroleum coke production unit after condensation, it will continue to be deeply condensed to produce a low-sulfur petroleum coke, thereby improving the utilization value of the oil product.

(4) According to the present invention, in a preferred embodiment, after the fraction rich in tricyclic and tetracyclic aromatics is separated for producing the needle coke, the remaining fraction is a high-quality starting material for producing a low-sulfur petroleum coke because it is rich in aromatics or colloid/asphaltene and has a very low sulfur content. The present invention utilizes the components in the starting material in a graded manner, greatly improving the effective utilization rate of catalytic slurry oil and ethylene tar.

Brief description of the drawings

[0010]

Figure 1 is a schematic diagram of a process for producing a needle coke with a mixed feedstock oil provided by the present invention.

Figure 2 shows the variation trend of TI content of the catalytic slurry oil used in the examples and comparative examples with the reaction temperature.

Figure 3 shows the variation trend of the TI content of the first feedstock oil used in Example 1 with the reaction temperature.

Figure 4 shows the variation trend of the TI content of the first feedstock oil used in Example 2 with the reaction temperature.

Figure 5 is a polarized light microstructure photograph of the needle coke obtained in Example 2.

Figure 6 shows the variation trend of the TI content of the first feedstock oil used in Example 3 with the reaction temperature.

Figure 7 is a polarized light microstructure photograph of the needle coke obtained in Example 3.

Figure 8 shows the variation trend of the TI content of the first feedstock oil used in Example 4 with the reaction temperature.

Figure 9 shows the variation trend of the TI content of the ethylene tar used in Comparative Example 2 with the reaction temperature.

Figure 10 is a polarized light microstructure photograph of the needle coke obtained in Comparative Example 2.

Figure 11 is a polarized light microstructure photograph of the needle coke obtained in Comparative Example 3.

Figure 12 shows the variation trend of the pressure in the furnace tube of the heating furnace of the needle coke production unit in comparative example 5 over the time.

Detailed description of the invention

[0011] The specific embodiments of the present invention are described in detail below, but it should be pointed out that the protection scope of the present invention is not limited by these specific embodiments, but is determined by the claims in the appendix.

[0012] All publications, patent applications, patents and other references mentioned in this specification are incorporated herein by reference. Unless otherwise defined, all technical and scientific terms used in this specification have the meanings conventionally understood by those skilled in the art. In the event of a conflict, the definitions in this specification shall prevail.

[0013] When this specification uses the prefix "well-known to those skilled in the art", "prior art" or similar expressions to introduce materials, substances, methods, steps, devices or components, the objects introduced by the prefix include those conventionally used in the field when this application is filed, but also include those that are not commonly used at present but will become generally recognized in the field to be suitable for similar purposes.

[0014] Unless explicitly stated otherwise, throughout the specification and claims, the terms "comprise/include/contain" or variations such as "comprises/includes/contains" or "comprising/including/containing", etc., will be understood to include the stated elements or components but not to exclude other elements or components.

[0015] In the context of this specification, for the convenience of description, spatial relative terms such as "lower", "bottom", "below", "under", "upper", "top", "above", "on", etc. may be used to describe the relationship between one element or feature and another element or feature in the accompanying drawings. It should be understood that the spatial relative terms are intended to include different orientations of the object in use or operation in addition to the orientation depicted in figures. For example, if the object in the figure is turned over, the element described as being "below" or "under" another elements or features will be oriented "above" or "on" the other element or feature.

[0016] Therefore, the exemplary term "below" can include two directions "below" and "above". Objects may also have other orientations (e.g., rotated 90 degrees or other orientations) and the spatial relative terms used herein should be interpreted accordingly.

[0017] In the context of this specification, the terms "first", "second", etc. are used to distinguish two different elements or parts, but are not used to limit specific positions or relative relationships.

[0018] In the context of the present specification, all numerical values of parameters (e.g., amounts or conditions) are to be understood as being modified in all instances by the term "about", regardless of whether "about" actually appears before the numerical value or not.

[0019] In the context of this specification, the catalytic slurry oil refers to heavy distillate oil produced by catalytic cracking reactions.

[0020] In the context of this specification, the ethylene tar refers to heavy distillate oil produced by an ethylene cracking unit.

[0021] In the context of this specification, the coke sulfur content is determined by the GB/T 24526 method.

[0022] In the context of this specification, the coke Hardgrove grindability index is measured by the GB/T 2565 method.

[0023] In the context of this specification, the coke particle strength is measured by the method in Appendix B of T/ZGTS 002.

[0024] In the context of this specification, the ash content of the coke is determined by the GB/T 1429 method.

[0025] In the context of this specification, the ash content of the oil product is determined by the GB/T 508 method.

[0026] In the context of this specification, the sulfur content of the oil product is determined by the SH/T 0689 method.

[0027] In the context of this specification, the aromatic carbon ratio of the oil product is determined by the SH/T 0793 method.

[0028] In the context of this specification, the method for measuring the coking starting temperature is as follows: a feedstock oil is left to stand at a certain temperature for 20 minutes, then the content of toluene insoluble (TI) matter is analyzed. At a time when the TI content is higher than 0.5wt%, the feedstock oil is deemed to have started to coke, and the temperature at this time is the coking starting temperature of the feedstock oil.

[0029] Unless otherwise specified, all percentages, parts, ratios, etc. mentioned in this specification are based on weight and the pressure refers to a gauge pressure.

[0030] In the context of this specification, any two or more embodiments of the present invention may be arbitrarily combined, and the technical solutions thus formed belong to part of the original disclosure of this specification and also fall within the protection scope of the present invention.

[0031] According to one embodiment of the present invention, a method for producing a needle coke is provided. According to the present invention, the method for producing a needle coke is carried out in the apparatus for producing a needle coke described below. For this reason, the contents not described in detail in the section of the method for producing can be directly referred to the relevant contents described below for the apparatus for producing.

[0032] According to one embodiment of the present invention, the method for producing a needle coke comprises the following steps:

(1) hydrotreating a mixture of a first feedstock oil and a second feedstock oil to obtain a hydrogenated product;
(2) cracking the hydrogenated product to obtain a cracked product;
(3) producing the needle coke with the cracked product as a starting material.

[0033] According to one embodiment of the present invention, the first feedstock oil has an aromatic carbon ratio of greater than 65mol% (preferably 70mol%-95mol%). If the aromatic carbon ratio is too low, it means that the aromatic hydrocarbon content is too low, or the aromatic ring contains too many side chains. After hydrogenation, the aromatic carbon ratio will be further reduced, and it will not be suitable as a starting material for producing the needle coke.

[0034] According to one embodiment of the present invention, the second feedstock oil has an aromatic carbon ratio of greater than 60mol% (preferably 70mol%-90mol%). If the aromatic carbon ratio is too low, it means that the aromatic hydrocarbon content is too low, or the aromatic ring contains too many side chains. After hydrogenation, the aromatic carbon ratio will be further reduced, and it will not be suitable as a starting material for producing the needle coke.

[0035] According to one embodiment of the present invention, the first feedstock oil has a coking starting temperature lower than that of the second feedstock oil by 10-140°C, preferably by 35-105°C. If the coking starting temperature of the first feedstock is too low, the coking is likely to occur in the hydrogenation reactor, and the reaction cannot proceed; if the coking starting temperature of the first feedstock is too high or is similar to that of the second feedstock, the hydrogenation saturation capacity of the first feedstock is probably similar to that of the second feedstock in the hydrotreating system, and the saturation of the aromatic ring of the second feedstock cannot be alleviated, resulting in an excessive reduction in the aromatic carbon ratio of the second feedstock after hydrogenation.

[0036] According to one embodiment of the present invention, the weight ratio of said second feedstock oil to said first feedstock oil is 1:1-1:0.001 (preferably 1:0.2-1:0.01). According to one embodiment of the present invention, said first feedstock oil has a coking starting temperature of 350°C-420°C, preferably 380°C-415°C.

[0037] According to one embodiment of the present invention, said second feedstock oil has a coking starting temperature of 430°C-490°C, preferably 450°C-485°C.

[0038] According to one embodiment of the present invention, said second feedstock oil is a catalytic slurry oil. Generally, the ash content of the catalytic slurry oil can meet the above requirements after a desolidification treatment, and the desolidification treatment can be carried out by one of or a combination of some of filtration, centrifugal sedimentation, flocculation sedimentation, electrostatic adsorption, or other manners, preferably by filtration.

[0039] According to one embodiment of the present invention, said second feedstock oil has an ash content of not higher than 0.01wt%, preferably not higher than 0.005wt%, and a sulfur content of higher than 0.5wt%, preferably 0.8wt%-1.5wt%.

[0040] According to one embodiment of the present invention, said first feedstock oil has an ash content of not higher than 0.01wt%, preferably not higher than 0.005wt%, and a sulfur content of not higher than 0.1wt%, preferably not higher than 0.03wt%.

[0041] According to one embodiment of the present invention, said first feedstock oil is an ethylene tar extract. Preferably, said first feedstock oil is prepared according to the following steps:

(i) extracting an ethylene tar with a solvent to obtain an extract phase and a raffinate phase;
(ii) removing the solvent from the extract phase to obtain an aromatics-enriched oil, and then separating said aromatics-enriched oil to obtain a first lighter oil and said first feedstock oil (first heavier oil).

[0042] According to one embodiment of the present invention, said solvent is selected from C3-C12 normal alkanes or cycloalkanes, preferably C5-C12 normal alkanes. According to one embodiment of the present invention, the mass ratio of said ethylene tar to said solvent is 1:0.5-1:5, preferably 1:1-1:2.

[0043] According to one embodiment of the present invention, the extraction is carried out in an extraction unit. To this end, the extraction unit comprises at least one extraction column. The extraction unit is operated at a temperature of 30°C-110°C, preferably 40°C-80°C. Preferably, the ethylene tar and the solvent are in countercurrent contact and mass transfer.

[0044] According to one embodiment of the present invention, the regenerated solvent is returned to the extraction unit for reuse.

[0045] According to one embodiment of the present invention, said first heavier oil has a 5% distillation temperature of 300°C-400°C, preferably 340°C-380°C.

[0046] According to one embodiment of the present invention, said first lighter oil has a 95% distillation temperature of 280°C-400°C (preferably 335°C-380°C).

[0047] According to one embodiment of the present invention, the first lighter oil is subjected to a condensation reaction to obtain a condensation product, and then the condensation product is used to produce the petroleum coke (low-sulfur petroleum coke). According to one embodiment of the present invention, before the cracking, the hydrogenated product is separated to obtain a lighter component (such as gas, naphtha) and a hydrogenated tail oil, and then the hydrogenated tail oil is cracked to obtain the cracked product.

[0048] According to one embodiment of the present invention, for the hydrogenation catalyst, alumina is used as support, oxides of Group VIB and/or Group VIII metals as active components, such as one of or a combination of some of oxides of metals such as Mo, W, Co, and Ni are supported thereon. The hydrogenation catalyst can be prepared by the existing methods in the art, or by using existing commercial catalysts, such as the FZC and/or FH series hydrogenation catalysts developed by Dalian Petroleum&Chemical Research Institute of SINOPEC.

[0049] According to one embodiment of the present invention, the operation conditions for said hydrotreating comprises: the reaction temperature is 310°C-450°C, preferably 340°C-390°C, the reaction pressure is 2MPa-20MPa, preferably 4MPa-8MPa, theHydrogen/oil volume ratio is 100-2500, preferably 800-1800, the LHSV by volume is $0.1h^{-1}$-$2.0h^{-1}$, preferably $0.6h^{-1}$-$1.2h^{-1}$.

[0050] According to one embodiment of the present invention, said hydrogenated tail oil has a 5% distillation temperature of 160°C-250°C, preferably 180°C-210°C.

[0051] According to one embodiment of the present invention, said hydrogenated tail oil has a sulfur content of not higher than 0.4wt% (preferably not higher than 0.35wt%).

[0052] According to one embodiment of the present invention, before being used to produce the needle coke, said cracked product is separated to produce a second lighter oil, a intermediate distillate oil and a second heavier oil, and then said intermediate distillate oil is used as a starting material to produce the needle coke.

[0053] According to one embodiment of the present invention, said cracking reaction unit is provided with at least one reactor, and the reactor type may be one of or a combination of some of tubular reactor, column reactor, and tank reactor, preferably column reactor. According to one embodiment of the present invention, said carrier gas can be one or more of water vapor, nitrogen gas, inert gas (e.g., helium gas, neon gas, argon gas and the like), preferably water vapor.

[0054] According to one embodiment of the present invention, the carrier gas may be one or more of water vapor, nitrogen, and an inert gas (such as helium, neon, argon, etc.), preferably water vapor.

[0055] According to one embodiment of the present invention, the operation condition of said cracking includes: the reaction temperature is 380°C-520°C, preferably 420°C-490°C, the reaction pressure is 0.1MPa-5MPa, preferably 0.2MPa-1.0MPa, the residual time is 0.01h-30h, preferably 0.1h-3h, the oil-to-steam mass ratio is 100:0.1-100:20, preferably 100:1-100:8.

[0056] According to one embodiment of the present invention, said intermediate distillate oil has a distillation range of 330°C-530°C (preferably 350°C-500°C).

[0057] According to one embodiment of the present invention, said second lighter oil has a 95% distillation temperature of 300°C-400°C (preferably 320°C-380°C). Correspondingly, said second heavier oil has a 5% distillation temperature of 460°C-550°C (preferably 485°C-510°C).

[0058] According to one embodiment of the present invention, at least a part of said second lighter oil is recycled back to said hydrotreating.

[0059] According to one embodiment of the present invention, at least a part of said second lighter oil is subjected to a condensation reaction to produce a condensation product, then said condensation product is used to produce the petroleum coke (low-sulfur petroleum coke).

[0060] According to one embodiment of the present invention, a part of said second lighter oil is recycled back to said hydrotreating, and the other part is subjected to the condensation reaction.

[0061] According to one embodiment of the present invention, a portion of the second lighter oil is recycled back to the hydrotreating, and the other portion undergoes the condensation reaction.

[0062] According to one embodiment of the present invention, said raffinate phase and said second heavier oil are mixed, and then the resulting mixture is used to produce the petroleum coke (low-sulfur petroleum coke).

[0063] According to one embodiment of the present invention, the mass ratio of said raffinate phase to said second heavier oil is 1:1-0.01:1 (preferably 0.5:1-0.1:1).

[0064] According to one embodiment of the present invention, said low-sulfur petroleum coke production at least comprises one heating furnace, two coke drums and one coking fractionation column. At least one of the coke drums is always in a reaction stage and at least one is in a purge and decoking stage.

[0065] According to one embodiment of the present invention, the operation conditions for producing the petroleum coke comprise: the outlet temperature of the heating furnace is 440°C-550°C, preferably 490°C-510°C, the coke drum top pressure is 0.01MPa-2.5MPa, preferably 0.1MPa-0.5MPa, and the reaction period is 10h-48h, preferably 18h-30h. It can be operated at a constant pressure or a changing pressure, preferably a constant pressure.

[0066] According to one embodiment of the present invention, said needle coke production at least comprises one heating furnace, two coke drums and one coking fractionation column. At least one of the coke drums is always in a reaction stage and at least one is in a purge and decoking stage.

[0067] According to one embodiment of the present invention, the operation conditions for producing the needle coke comprise: the outlet temperature of the heating furnace is 420°C-560°C, preferably 440°C-530°C, and the heating rate is 0.5°C/h-30°C/h. The coke drum top pressure is 0.01MPa-2.5MPa, preferably 0.2MPa-1.3MPa. It can be operated at a constant pressure or a changing pressure. If the changing pressure operation is adopted, the changing pressure rate is 0.1MPa/h-5MPa/h. The reaction period is generally 10h-72h, preferably 32h-54h.

[0068] According to one embodiment of the present invention, the condensation reaction may be carried out without adding a condensation catalyst, or with adding a condensation catalyst, preferably with adding a condensation catalyst. The condensation catalyst comprises a support and an active component, wherein the support is one or more of kaolin, montmorillonite, alumina, and silicon-containing alumina, preferably alumina; the active component is at least one of the oxides of Group IVB and/or Group VIB metals, and the active metal may be selected from at least one of zirconium, tungsten, and molybdenum; based on the weight of the catalyst, the content of the active component is 0.1wt%-50wt%, preferably 5wt%-25wt%. The shape of the condensation catalyst may be one or more of spherical, cylindrical, three-leaf clover, four-leaf clover, Raschig ring, etc.

[0069] According to one embodiment of the present invention, the operation conditions of the condensation reaction comprises: the reaction temperature is 350°C-530°C, preferably 380°C-450°C, the reaction pressure is 0.01MPa-5MPa, preferably 1MPa-3MPa, the residual time is 0.1h-15h, preferably 0.5h-6h.

[0070] According to one embodiment of the present invention, said condensation reaction is provided with at least one reactor, preferably a fixed bed reactor. The fixed bed reactor has at least one feeding inlet and one discharging outlet.

[0071] According to one embodiment of the present invention, it also relates to a apparatus for producing a needle coke. According to the present invention, the apparatus for producing said needle coke is specifically used to implement the above-described method for producing the needle coke. For this reason, the contents not described in detail in the section of the apparatus for producing can be directly referred to the relevant contents described in the whole context for the method for producing. According to one embodiment of the present invention, the apparatus for producing said needle coke comprises the following units:

a feedstock oil supplying unit, which is configured for providing a first feedstock oil and a second feedstock oil;
a hydrogenation unit, which is configured for hydrotreating a mixture of the first feedstock oil and the second feedstock oil to obtain a hydrogenated product;
a cracking unit, which is configured for cracking the hydrogenated product to obtain a cracked product;
a needle coke production unit, which is configured for producing the needle coke with the cracked product as a starting material.

[0072] According to one embodiment of the present invention, the apparatus for producing comprises the following units:

an extraction unit, which is configured for receiving an ethylene tar and a solvent,
which are treated to produce an extract phase and a raffinate phase;
a solvent recovery unit, which is configured for receiving the extract phase from the extraction unit, which is separated to produce a regenerated solvent and and an aromatics-enriched oil;
a first separation unit, which is configured for receiving the aromatics-enriched oil from the solvent recovery unit, which is cut to produce a first lighter oil and a first heavier oil (corresponding to said first feedstock oil);
a hydrogenation reaction unit, which is configured for receiving said first feedstock oil and a catalytic slurry oil (corresponding to said second feedstock oil), which are subjected to a hydrogenation reaction in the presence of hydrogen gas and a hydrogenation catalyst;
a hydrogenation separation unit, which is configured for receiving a hydrogenated product from the hydrogenation reaction unit, which is separated to produce a gas, a naphtha, and a hydrogenated tail oil;
a cracking reaction unit, which is configured for receiving the hydrogenated tail oil from the hydrogenation separation unit, which is subjected to a cracking reaction in the presence of a carrier gas
a second separation unit, which is configured for receiving a cracked product from the cracking reaction unit, which is separated to produce a second lighter oil, a intermediate distillate oil and a second heavier oil; and

a needle coke production unit, which is configured for receiving said intermediate distillate oil, which is reacted to produce the needle coke.

[0073] According to one embodiment of the present invention, said extraction unit comprises at least one extraction column. The extraction column can be any form of extraction equipment currently available in the art without any particular limitation. Those skilled in the art can freely select it according to actual conditions.

[0074] According to one embodiment of the present invention, it comprises a condensation reaction unit, which is used to receive a first lighter oil from a first separation unit. The condensation reaction product is sent via pipeline to a low-sulfur petroleum coke production unit to be treated. The condensation reaction unit is provided with at least one reactor, preferably a fixed bed reactor.

[0075] According to one embodiment of the present invention, the regenerated solvent obtained in the solvent recovery unit is returned via pipeline to the extraction unit for reuse.

[0076] According to one embodiment of the present invention, the hydrogenation reaction unit comprises at least one hydrogenation reactor, When two or more hydrogenation reactors exist, there is no particular restriction on the connection mode between the reactors, and they are generally connected in series. The reactor can be one of or a combination of some of an ebullated bed reactor, a suspended bed reactor, a fixed bed reactor and the like, preferably a fixed bed reactor.

[0077] According to one embodiment of the present invention, the hydrogenation separation unit comprises a high-temperature & high-pressure separator, a low-temperature & high-pressure separator, a high-temperature & low-pressure separator, a low-temperature & low-pressure separator, and can also comprise a stripping column, a fractionation column and the like.

[0078] According to one embodiment of the present invention, the first separation system may be one of or a combination of some of a stripping column, a flash column, a fractionation column and the like, preferably a fractionation column.

[0079] According to one embodiment of the present invention, the second separation unit may be one of or a combination of some of a stripping column, a flash column, a fractionation column and the like, preferably a fractionation column.

[0080] According to one embodiment of the present invention, the second lighter oil obtained from the second separation unit is recycled back via pipeline to a hydrotreating unit; or sent to the condensation reaction unit to carry out the condensation reaction to produce the condensation product, which is sent to the low-sulfur petroleum coke production unit to produce the low-sulfur petroleum coke; or a part is recycled back to the hydrotreating unit; and the residual part is sent to the condensation reaction unit.

[0081] According to one embodiment of the present invention, the low-sulfur petroleum coke production unit at least comprises one heating furnace, two coke drums and one coking fractionation column. At least one of the coke drums is always in a reaction stage and at least one is in a purge and decoking stage.

[0082] According to one embodiment of the present invention, the needle coke production unitat least comprises one heating furnace, two coke drums and one coking fractionation column. At least one of the coke drums is always in a reaction stage and at least one is in a purge and decoking stage.

[0083] One specific embodiment of the present invention is described in detail below in conjunction with the accompanying drawings.

[0084] As shown in Figure 1, according to the present invention, ethylene tar 2 is sent to an extraction unit 9 to contacted with a solvent 14 to produce an extract phase 16 and a raffinate phase 15, wherein the extract phase 16 is sent to a solvent recovery unit 10, and separated to produce a regenerated solvent 18 and an aromatic-rich oil 17; the regenerated solvent 18 is returned to the extraction unit 9 for recycling, and the aromatic-rich oil is sent to a first separation unit 11 and separated to produce a first lighter oil 19 and a first heavier oil 20, wherein the first lighter oil 19 can be discharged or sent to a condensation reaction unit 5 to carry out the condensation reaction to produce a condensation reaction product 27, which is sent together with the raffinate phase 15 to a low-sulfur petroleum coke production unit 8; the first heavier oil 20, a catalytic slurry oil 1 and a hydrogen gas 30 are sent to a hydrogenation reaction unit 3 to carry out the hydrogenation reaction in the presence of a hydrogenation catalyst to produce a hydrogenated product 21, which is sent to a hydrogenation separation unit 4 and separated to produce a gas 28, a naphtha 29 and a hydrogenated tail oil 22; the obtained hydrogenated tail oil 22 is sent to a cracking reaction unit 6 to carry out the cracking reaction in the presence of a carrier gas 7 to produce a cracked product 23, which is sent to a second separation unit 12 and separated to produce a second lighter oil 24, an intermediate distillate oil 25 and a second heavier oil 26; the obtained second heavier oil 26 is sent to the low-sulfur petroleum coke production unit 8 to produce the low-sulfur petroleum coke; the obtained intermediate distillate oil 25 is sent to a needle coke production unit 13 to produce the needle coke; the second lighter oil 24 can be recycled back to the hydrogenation reaction unit 3 for treatment, or can also be sent to the condensation reaction 5 for treatment, or a part can be recycled back to the hydrogenation reaction unit 3 for treatment, and the residual part can be sent to the condensation reaction 5 for treatment.

Examples

[0085] The present invention is further described in detail below using examples, but the present invention is not limited to these examples.

[0086] The properties of a catalytic slurry oil (second feedstock oil) and an ethylene tar as a starting materials of the examples and the comparative examples of the present invention are shown in Table 1. The variation trend of the TI content of the catalytic slurry oil with the reaction temperature is shown in Figure 2. The second feedstock oil has a coking starting temperature between 460-465°C. The extractant used in the extraction unit is n-heptane. The used hydrogenation catalyst is the FZC-34BT hydrogenation catalyst developed by the Dalian Petroleum&Chemical Research Institute of SINOPEC. The carrier gas used in the cracking treatment unit is water vapor.

Example 1

[0087] Ethylene tar was sent to an extraction unit to contact with an extractant, and the resulting mixture was separated to produce a raffinate phase and an aromatics-enriched oil. The aromatics-enriched oil was separated to produce a first lighter oil and a first heavier oil. The first heavier oil was subjected to a mild hydrotreating to produce a first feedstock oil. A catalytic slurry oil and the first feedstock oil were mixed at a mass ratio of 1:0.1 and sent to a hydrogenation reaction unit. The resulting hydrogenated product was separated to produce a hydrogenated tail oil. The hydrogenated tail oil was sent to a cracking reaction unit. The resulting cracked product was separated to produce a intermediate distillate oil. The intermediate distillate oil was sent to a needle coke production unit to produce a needle coke. The operation parameters for the extraction unit, the hydrogenation reaction unit, the cracking reaction unit, and the needle coke production unit were listed in Table 2.

[0088] The variation trend of the TI content of the first feedstock oil with the reaction temperature is shown in Figure 3. The first feedstock oil had a coking starting temperature of about 440°C.

[0089] The properties of the first feedstock are listed in Table 3.

[0090] The properties of the needle coke are listed in Table 4.

Example 2

[0091] Ethylene tar was sent to an extraction unit to contact with an extractant, and the resulting mixture was separated to produce a raffinate phase and an aromatics-enriched oil. The aromatics-enriched oil was separated to produce a first lighter oil and a first heavier oil. The first heavier oil was used as a first feedstock oil. A catalytic slurry oil and the first feedstock oil were mixed at a mass ratio of 1:2, and sent to a hydrogenation reaction unit. The resulting hydrogenated product was separated to produce a hydrogenated tail oil. The hydrogenated tail oil was sent to a cracking reaction unit. The resulting cracked product was separated to produce a intermediate distillate oil. The intermediate distillate oil was sent to a needle coke production unit to produce a needle coke. The operation parameters for the extraction unit, the hydrogenation reaction unit, the cracking reaction unit, and the needle coke production unit were listed in Table 2.

[0092] The variation trend of the TI content of the first feedstock oil with the reaction temperature is shown in Figure 4. The first feedstock oil has a coking starting temperature between 400-405°C.

[0093] The properties of the first feedstock are listed in Table 3.

[0094] The properties of the needle coke are listed in Table 4.

[0095] The polarized light microstructure of the needle coke is shown in Figure 5. The microstructure of the needle coke obtained in Example 2 is mainly composed of large flakes, with less fiber structure.

Example 3

[0096] Ethylene tar was sent to an extraction unit to contact with an extractant, and the resulting mixture was separated to produce a raffinate phase and an aromatics-enriched oil. The aromatics-enriched oil was separated to produce a first lighter oil and a first heavier oil. The first heavier oil was used as a first feedstock oil. A catalytic slurry oil and the first feedstock oil were mixed at a mass ratio of 1:0.08, and sent to a hydrogenation reaction unit. The resulting hydrogenated product was separated to produce a hydrogenated tail oil. The hydrogenated tail oil

[0097] The resulting cracked product was separated to produce a second lighter oil, a intermediate distillate oil and a second heavier oil. The intermediate distillate oil was sent to a needle coke production unit to produce a needle coke. The operation parameters for the extraction unit, the hydrogenation reaction unit, the cracking reaction unit, and the needle coke production unit were listed in Table 2.

[0098] The raffinate phase obtained from the extraction unit and the second heavier oil from the second separation unit were mixed and sent to a low-sulfur petroleum coke production unit, the operation conditions for which comprised: the outlet temperature of the heating furnace: 497°C, the coke drum top pressure: 0.45MPa, and the reaction period: 28h.

[0099] The properties of the first feedstock are listed in Table 3.

[0100] The variation trend of the TI content of the first feedstock oil with the reaction temperature is shown in Figure 6. The first feedstock oil had a coking starting temperature between 405-410°C.

[0101] The properties of the needle coke are listed in Table 4.

[0102] The polarized fiber structure of the needle coke is shown in Figure 7. The organizational structure of the needle coke obtained in Example 3 contained a large amount of fiber structures.

[0103] The sulfur content of the low-sulfur petroleum coke is listed in Table 5.

Example 4

[0104] This example was basically carried out in the same manner as that of Example 3, except that the first lighter oil obtained from the first separation unit was sent to the condensation reaction unit; the condensation catalyst support was alumina; the active component was 7.5wt%ZrO_2-3.6wt%MoO_2 in three-leaf clover structure; and a condensation product was obtained from the condensation reaction unit, wherein the reaction temperature was 426°C, the reaction pressure was 1.3MPa, and the residual time was 1.5h. The condensation product was mixed with a raffinate phase obtained from the extraction unit, and a second heavier oil obtained from the second separation unit, and the resulting mixture was sent to a low-sulfur petroleum coke production unit. The operation parameters for the extraction unit, the hydrogenation reaction unit, the cracking reaction unit, and the needle coke production unit were listed in Table 2.

[0105] The properties of the first feedstock are listed in Table 3.

[0106] The variation trend of the TI content of the first feedstock oil with the reaction temperature is shown in Figure 8. The first feedstock oil had a coking starting temperature between 407-410°C.

[0107] The properties of the needle coke are listed in Table 4.

[0108] The sulfur content of the low-sulfur petroleum coke is listed in Table 5.

Comparative Example 1

[0109] A catalytic slurry oil was sent to the hydrogenation reaction unit. The resulting hydrogenated product was separated to produce a hydrogenated tail oil. The hydrogenated tail oil was sent to a cracking reaction unit. The resulting cracked product was separated to produce a intermediate distillate oil. The intermediate distillate oil was sent to a needle coke production unit to produce a needle coke. The operation parameters for the hydrogenation reaction unit, the cracking reaction unit, and the needle coke production unit are listed in Table 6.

[0110] The properties of needle coke are listed in Table 7.

Comparative Example 2

[0111] An ethylene tar was sent to the hydrogenation reaction unit. The resulting hydrogenated product was separated to produce a hydrogenated tail oil. The hydrogenated tail oil was sent to a cracking reaction unit. The resulting cracked product was separated to produce a intermediate distillate oil. The intermediate distillate oil was sent to a needle coke production unit to produce a needle coke. The operation parameters for the hydrogenation reaction unit, the cracking reaction unit, and the needle coke production unit are listed in Table 6.

[0112] The variation trend of the TI content of the ethylene tar with the reaction temperature is shown in Figure 9. The ethylene tar had a coking starting temperature between 395-397°C. The properties of needle coke are listed in Table 7.

[0113] The polarized fiber structure of the needle coke is shown in Figure 10. The needle coke obtained in Comparative Example 2 had a poor texture, mainly in the form of large flakes and mixed with mosaic structures.

Comparative Example 3

[0114] A catalytic slurry oil and an ethylene tar were mixed at a mass ratio of 1:0.1, and sent to the hydrogenation reaction unit. The resulting hydrogenated product was separated to produce a hydrogenated tail oil; the hydrogenated tail oil was sent to the needle coke production unit to produce the needle coke. The operation parameters for the hydrogenation reaction unit and the needle coke production unit are listed in Table 6.

[0115] The properties of needle coke are listed in Table 7.

[0116] The polarized fiber structure of the needle coke is shown in Figure 11. The needle coke obtained in Comparative Example 3 had a poor texture and contained a large amount of mosaic structures.

Comparative Example 4

[0117] A catalytic slurry oil and an ethylene tar were mixed at a mass ratio of 1:0.12, and sent to the cracking reaction unit.

The resulting cracked product was separated to produce a intermediate distillate oil. The intermediate distillate oil was sent to a needle coke production unit to produce a needle coke. The operation parameters for the cracking reaction unit and the needle coke production unit are listed in Table 6.

[0118] The properties of needle coke are listed in Table 7.

Comparative Example 5

[0119] A catalytic slurry oil and an ethylene tar were mixed at a mass ratio of 1:0.05, and directly sent to the needle coke production unit to produce the needle coke. The operation parameters for the needle coke production unit is listed in Table 6.

[0120] The properties of needle coke are listed in Table 7.

[0121] The variation trend of the pressure in the furnace tube of the heating furnace of the needle coke production unit over the time is shown in Figure 12. There was a serious coking phenomenon in the furnace tube of the coking heating furnace of Comparative Example 5, and the apparatus could not be operated for a long period of time.

Table 1: Starting material properties

Item	Ethylene tar	Catalytic slurry oil (second feedstock oil)
Ash, wt%	0.012	0.004
Sulfur, wt%	0.023	1.107
Distillation range distribution/°C		
5%	213.2	316.6
95%	691.8	596.4
Aromatic carbon ratio, mol %	88.5	81.6

Table 2: Operation parameters of each unit in Examples

Reaction conditions	Example 1	Example 2	Example 3	Example 4
Extraction unit				
Solvent	n-pentane:iso-butane=1:2			
Ethylene tar:solvent (mass ratio)	1:1.8			
Hydrogenation reaction unit				
Temperature/°C	362	365	368	365
Pressure/MPa	6.1	5.6	5.8	5.9
Hydrogen/oil volume ratio	1200	1100	1200	1200
LHSV/h^{-1}	1.0	0.8	0.8	1.0
Cracking reaction unit				
Temperature/°C	445	430	452	447
Pressure/MPa	0.55	0.45	0.5	0.52
Residual time/h	1.1	0.6	0.8	1.0
Mass ratio of first heavier oil to water vapor	100:6			
Needle coke production unit				
Heating furnace temperature/°C	450-505			
Heating rate/°C·h^{-1}	5			
Coke drum top pressure/MPa	0.8			
Reaction period/h	48			

Table 3: Properties of the first feedstock oil in each example

Item	Example 1	Example 2	Example 3	Example 4
Sulfur content, wt%	0.011	0.021	0.018	0.020
Ash, wt%	0.003	0.001	0.002	0.003
Aromatic carbon ratio, mol%	78.2	86.6	84.7	86.2

Table 4: Properties of the needle coke in each Example

Item	Example 1	Example 2	Example 3	Example 4
Sulfur, wt%	0.385	0.39	0.36	0.37
Hardgrove grindability index	86	72	75	68
Particle strength, wt%	20.5	24.4	23.2	23.8

Table 5: Properties of low sulfur petroleum cokes

Item	Example 3	Example 4
sulfur content, wt%	0.41	0.39

Table 6: Operation parameters of each unit in Comparative Examples

Reaction conditions	Comparativ e Example 1	Comparativ e Example 2	Comparativ e Example 3	Comparativ e Example 4	Comparativ e Example 5
Hydrogenation reaction unit					
Temperature/ °C	369	360	367	-	-
Pressure/MPa	5.6	5.6	5.7	-	-
Hydrogen/oil volume ratio	1200	1100	1100	-	-
LHSV/h^{-1}	1.1	1.1	1	-	-
Cracking reaction unit					
Temperature/ °C	466	423	-	425	-
Pressure/MPa	0.55	0.3	-	0.25	-
Residual time/h	1.1	0.4	-	0.3	-
Mass ratio of first heavier oil to water vapor	100:6				
Needle coke production unit					
Heating furnace temperature/ °C	450-505				
Heating rate/°C·h^{-1}	5				
Coke drum top pressure/MPa	0.8				
Reaction period/h	48				

Table 7: Properties of the needle coke in each comparative example

Item	Comparativ e Example 1	Comparativ e Example 2	Comparativ e Example 3	Comparativ e Example 4	Comparativ e Example 5
Sulfur, wt%	0.37	0.13	0.35	1.18	1.17
Hardgrove grindabilit y index	90	85	98	63	58

(continued)

Item	Comparativ e Example 1	Comparativ e Example 2	Comparativ e Example 3	Comparativ e Example 4	Comparativ e Example 5
Particle strength, wt%	17.8	20.3	16.5	25.3	24.9

[0122] Although the Hardgrove grindability index and the particle strength of Comparative Examples 4 and 5 were relatively high, however the sulfur contents were >0.5wt%, not meeting the quality index of the needle coke.

Claims

1. A method for producing a needle coke, comprising the following steps:

    (1) hydrotreating a mixture of a first feedstock oil and a second feedstock oil to obtain a hydrogenated product;
    (2) cracking the hydrogenated product to obtain a cracked product;
    (3) producing the needle coke with the cracked product as a starting material, wherein the first feedstock oil has an aromatic carbon ratio of greater than 65mol% (preferably 70mol%-95mol%), the second feedstock oil has an aromatic carbon ratio of greater than 60mol% (preferably 70mol%-90mol%), and the first feedstock oil has a coking starting temperature lower than that of the second feedstock oil by 10-140°C, preferably by 35-105°C.

2. The method according to claim 1, wherein the weight ratio of said second feedstock oil to said first feedstock oil is 1:1-1:0.001 (preferably 1:0.2-1:0.01).

3. The method according to claim 1, wherein said first feedstock oil has a coking starting temperature of 350°C-420°C, preferably 380°C-415°C, said second feedstock oil has a coking starting temperature of 430°C-490°C, preferably 450°C-485°C.

4. The method according to claim 1, wherein said second feedstock oil is a catalytic slurry oil, said first feedstock oil is an ethylene tar extract.

5. The method according to claim 1, wherein said second feedstock oil has an ash content of not higher than 0.01wt%, preferably not higher than 0.005wt%, and a sulfur content of higher than 0.5wt%, preferably 0.8wt%-1.5wt%, and said first feedstock oil has an ash content of not higher than 0.01wt%, preferably not higher than 0.005wt%, and a sulfur content of not higher than 0.1wt%, preferably not higher than 0.03wt%.

6. The method according to claim 1, wherein said first feedstock oil is prepared according to the following steps:

    (i) extracting an ethylene tar with a solvent to obtain an extract phase and a raffinate phase;
    (ii) removing the solvent from the extract phase to obtain an aromatics-enriched oil, and then separating said aromatics-enriched oil to obtain a first lighter oil and said first feedstock oil (i.e. a first heavier oil).

7. The method according to claim 6, wherein said solvent is selected from C3-C12 normal alkanes or cycloalkanes, preferably from C5-C12 normal alkanes, and/or, the mass ratio of said ethylene tar to said solvent is 1:0.5-1:5, preferably 1:1-1:2.

8. The method according to claim 6, wherein said extraction is performed at a temperature of 30°C-110°C, preferably 40°C-80°C.

9. The method according to claim 6, wherein said first heavier oil has a 5% distillation temperature of 300°C-400°C, preferably 340°C-380°C.

10. The method according to claim 6, wherein said first lighter oil has a 95% distillation temperature of 280°C-400°C (preferably 335°C-380°C), and/or, said first lighter oil is subjected to a condensation reaction to produce a condensation product, then said condensation product is used to produce a petroleum coke.

11. The method according to claim 10, wherein the operation conditions of the condensation reaction comprise: a reaction

temperature of 350°C-530°C, preferably 380°C-450°C, a reaction pressure of 0.01MPa-5MPa, preferably 1MPa-3MPa, a residual time of 0.1h-15h, preferably 0.5h-6h.

12. The method according to claim 1, wherein before the cracking, the hydrogenated product is separated to obtain a lighter component (such as gas, naphtha) and a hydrogenated tail oil, and then the hydrogenated tail oil is cracked to obtain the cracked product.

13. The method according to claim 1, wherein the operation conditions for said hydrotreating comprise: a reaction temperature of 310°C-450°C, preferably 340°C-390°C, a reaction pressure of 2MPa-20MPa, preferably 4MPa-8MPa, a hydrogen/oil volume ratio of 100-2500, preferably 800-1800, an LHSV by volume of $0.1h^{-1}$-$2.0h^{-1}$, preferably $0.6h^{-1}$-$1.2h^{-1}$.

14. The method according to claim 12, wherein said hydrogenated tail oil has a 5% distillation temperature of 160°C-250°C, preferably 180°C-210°C, and/or, said hydrogenated tail oil has a sulfur content of not higher than 0.4wt% (preferably not higher than 0.35wt%).

15. The method according to claim 1, wherein before being used to produce the needle coke, said cracked product is separated to produce a second lighter oil, an intermediate distillate oil and a second heavier oil, and then said intermediate distillate oil is used as a starting material to produce the needle coke.

16. The method according to claim 15, wherein the operation conditions of said cracking include: a reaction temperature of 380°C-520°C, preferably 420°C-490°C, a reaction pressure of 0.1MPa-5MPa, preferably 0.2MPa-1.0MPa, a residual time of 0.01h-30h, preferably 0.1h-3h, an oil-to-steam mass ratio of 100:0.1-100:20, preferably 100:1-100:8.

17. The method according to claim 15, wherein said intermediate distillate oil has a distillation range of 330°C-530°C (preferably 350°C-500°C).

18. The method according to claim 15, wherein said second lighter oil has a 95% distillation temperature of 300°C-400°C (preferably 320°C-380°C), said second heavier oil has a 5% distillation temperature of 460°C-550°C (preferably 485°C-510°C).

19. The method according to claim 15, wherein at least a part of said second lighter oil is recycled back to said hydrotreating; or at least a part of said second lighter oil is subjected to a condensation reaction to produce a condensation product, then said condensation product is used to produce a petroleum coke; or a part of said second lighter oil is recycled back to said hydrotreating, and the other part is subjected to the condensation reaction.

20. The method according to claim 6, wherein said raffinate phase and said second heavier oil are mixed, and then the resulting mixture is used to produce a petroleum coke, and/or, the mass ratio of said raffinate phase to said second heavier oil is 1:1-0.01:1 (preferably 0.5:1-0.1:1).

21. The method according to claim 10 or 20, wherein the operation conditions for producing the petroleum coke comprise: a heating furnace outlet temperature of 440°C-550°C, preferably 490°C-510°C, a coke drum top pressure of 0.01MPa-2.5MPa, preferably 0.1MPa-0.5MPa, and a reaction duration of 10h-48h, preferably 18h-30h.

22. The method according to claim 1, wherein the operation conditions for producing said needle coke: a heating furnace outlet temperature of 420°C-560°C, preferably 440°C-530°C, a coke drum top pressure of 0.01MPa-2.5MPa, preferably 0.2MPa-1.3MPa, and a reaction duration of 10h-72h, preferably 32h-54h.

23. An apparatus for producing a needle coke, comprises the following units:

a feedstock oil supplying unit, which is configured for providing a first feedstock oil and a second feedstock oil;
a hydrogenation unit, which is configured for hydrotreating a mixture of the first feedstock oil and the second feedstock oil, to obtain a hydrogenated product;
a cracking unit, which is configured for cracking the hydrogenated product to obtain a cracked product;
a needle coke production unit, which is configured for producing the needle coke with the cracked product as a starting material,
wherein the first feedstock oil has an aromatic carbon ratio of greater than 65mol% (preferably 70mol%-95mol%), the second feedstock oil has an aromatic carbon ratio of greater than 60mol% (preferably 70mol%-90mol%), and

the first feedstock oil has a coking starting temperature lower than that of the second feedstock oil by 10-140°C, preferably by 35-105°C.

24. The apparatus according to claim 23, comprises the following units:

an extraction unit, which is configured for receiving an ethylene tar and a solvent and then treating same to produce an extract phase and a raffinate phase;
a solvent recovery unit, which is configured for receiving the extract phase from the extraction unit, and then separating same to produce a regenerated solvent and an aromatics-enriched oil;
a first separation unit, which is configured for receiving the aromatics-enriched oil from the solvent recovery unit, and then cutting same to produce a first lighter oil and
a first heavier oil (corresponding to said first feedstock oil);
a hydrogenation reaction unit, which is configured for receiving said first feedstock oil and a catalytic slurry oil (corresponding to said second feedstock oil), and then subjecting same to a hydrogenation reaction in the presence of hydrogen gas and a hydrogenation catalyst;
a hydrogenation separation unit, which is configured for receiving a hydrogenated product from the hydrogenation reaction unit, and then separating same to produce gas, naphtha, and a hydrogenated tail oil;
a cracking reaction unit, which is configured for receiving the hydrogenated tail oil from the hydrogenation separation unit, and then subjecting same to a cracking reaction in the presence of a carrier gas,
a second separation unit, which is configured for receiving a cracked product from the cracking reaction unit, and then separating same to produce a second lighter oil, an intermediate distillate oil and a second heavier oil; and
a needle coke production unit, which is configured for receiving said intermediate distillate oil, and then subjecting same to a reaction to produce the needle coke.

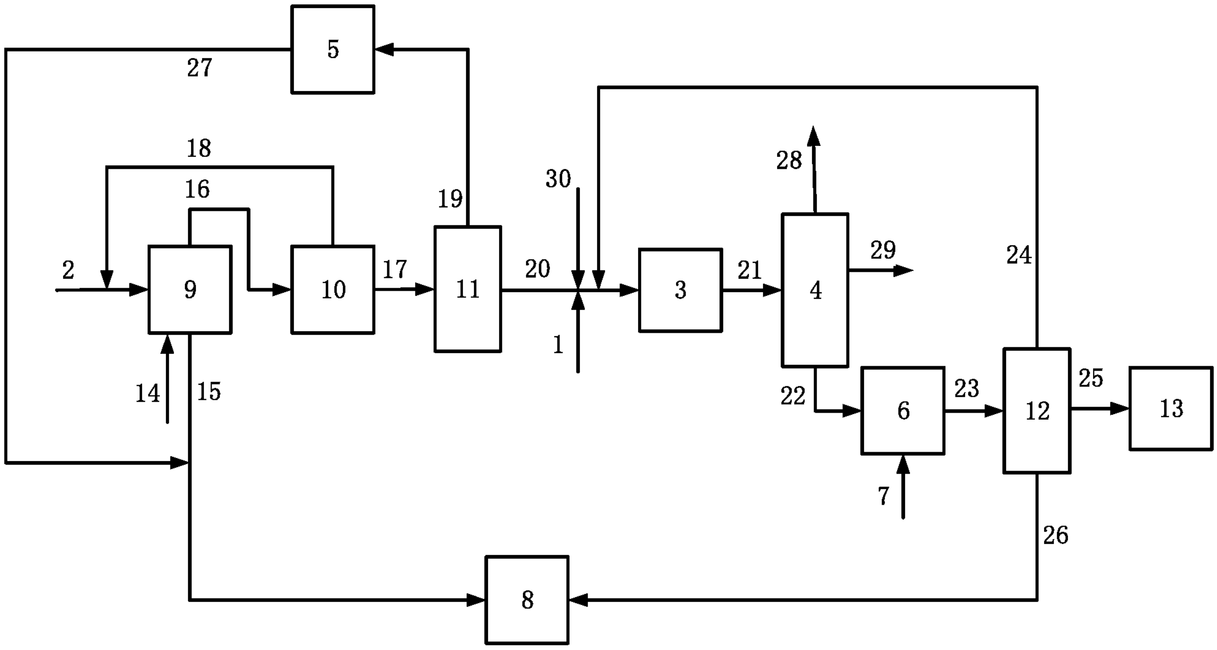
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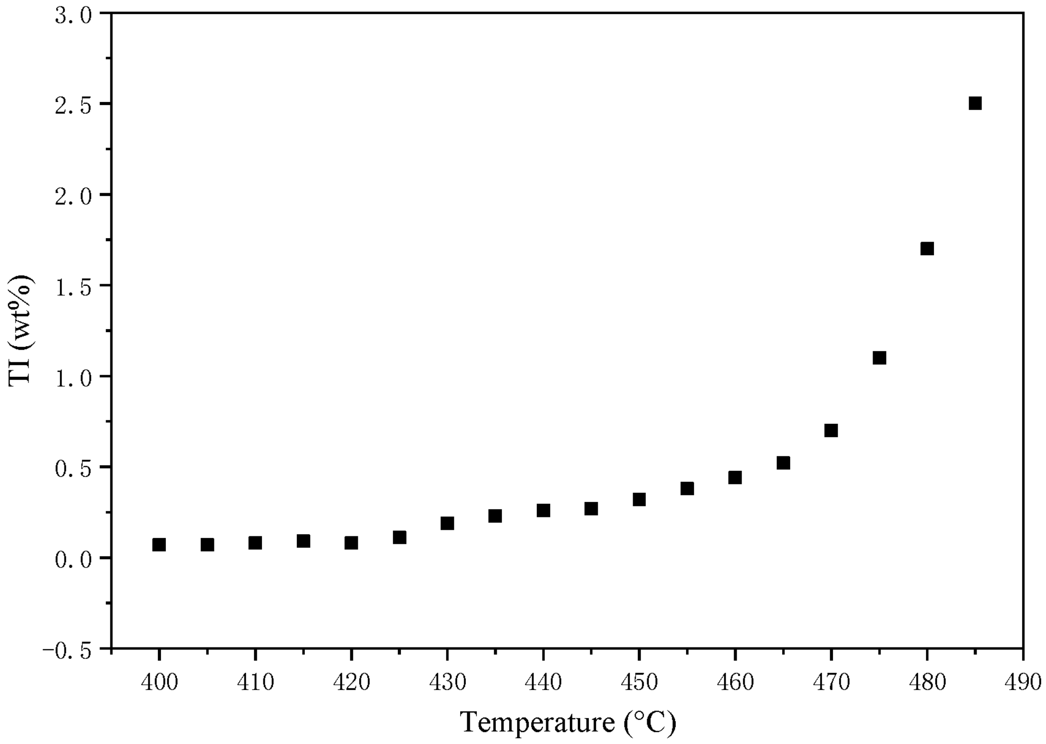
Fig. 1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1.0
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420
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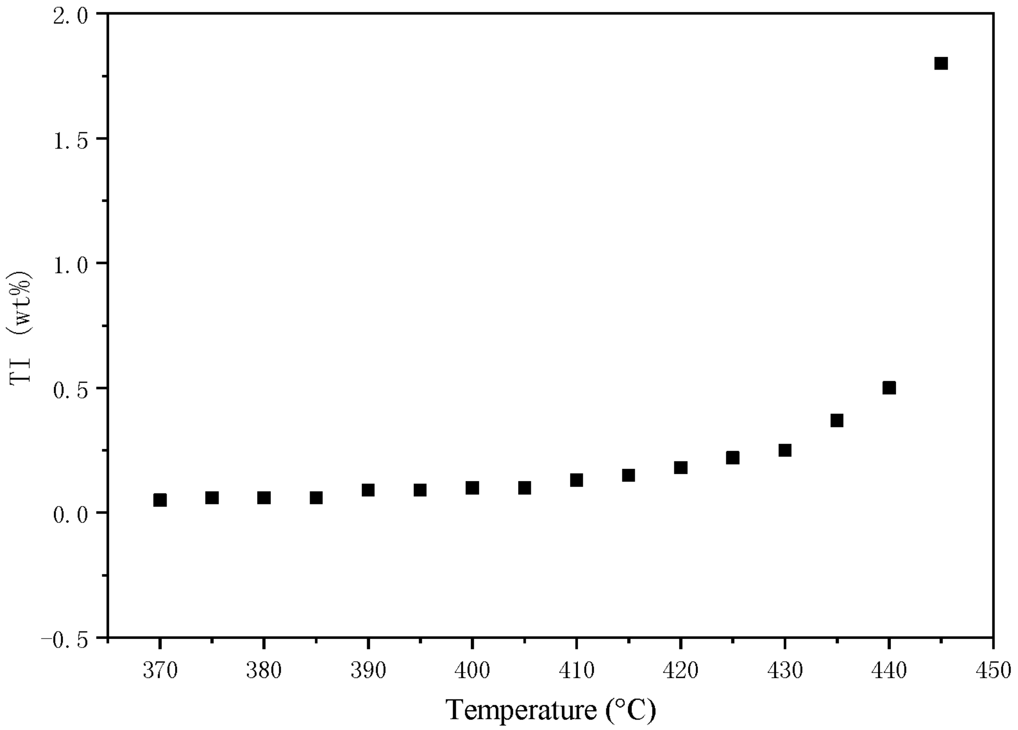
440
450
460
470
480
490
Temperature (°C)

Fig. 2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1.0
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TI（wt%）
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400
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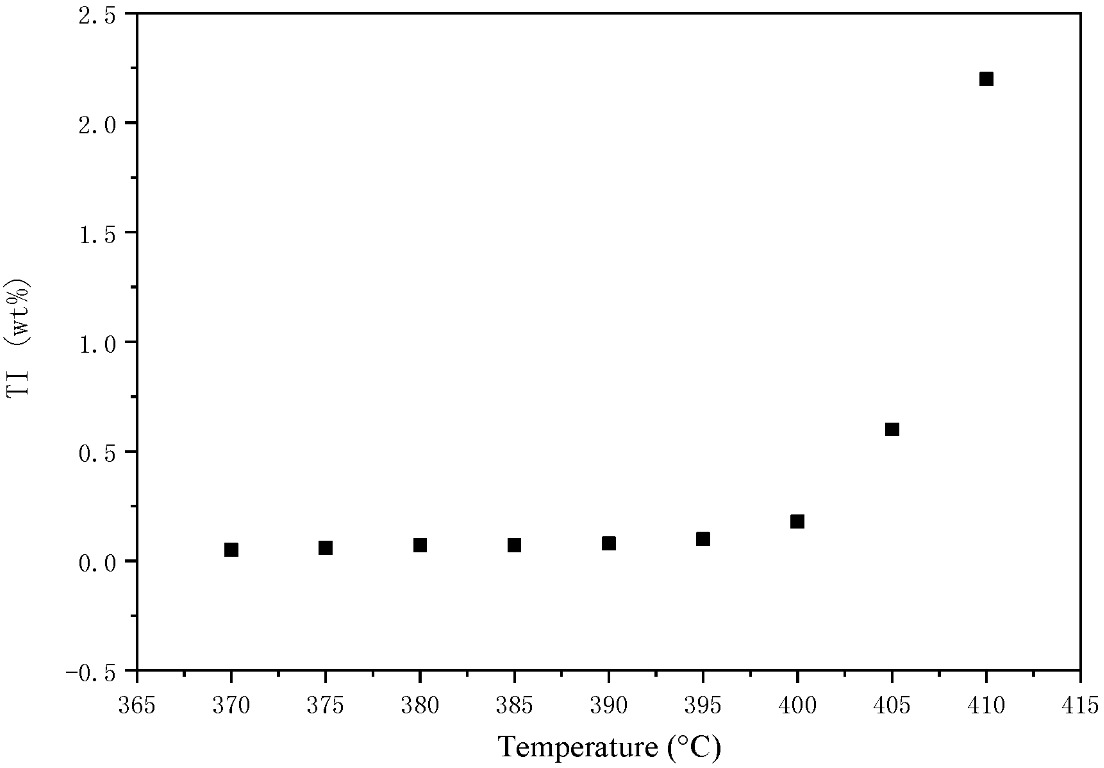
440
450
Temperature (°C)

Fig. 3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1.0
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0.0
−0.5
TI（wt%）
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380
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390
395
400
405
410
415
Temperature (°C)

Fig. 4

Fig. 5

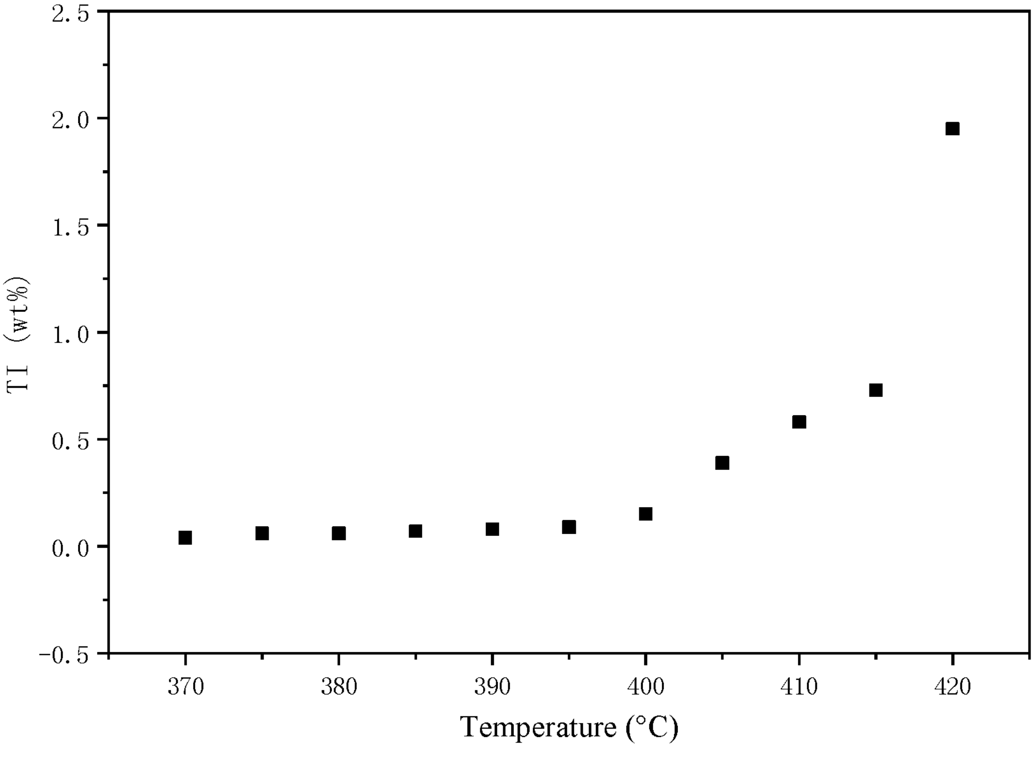

Fig. 6

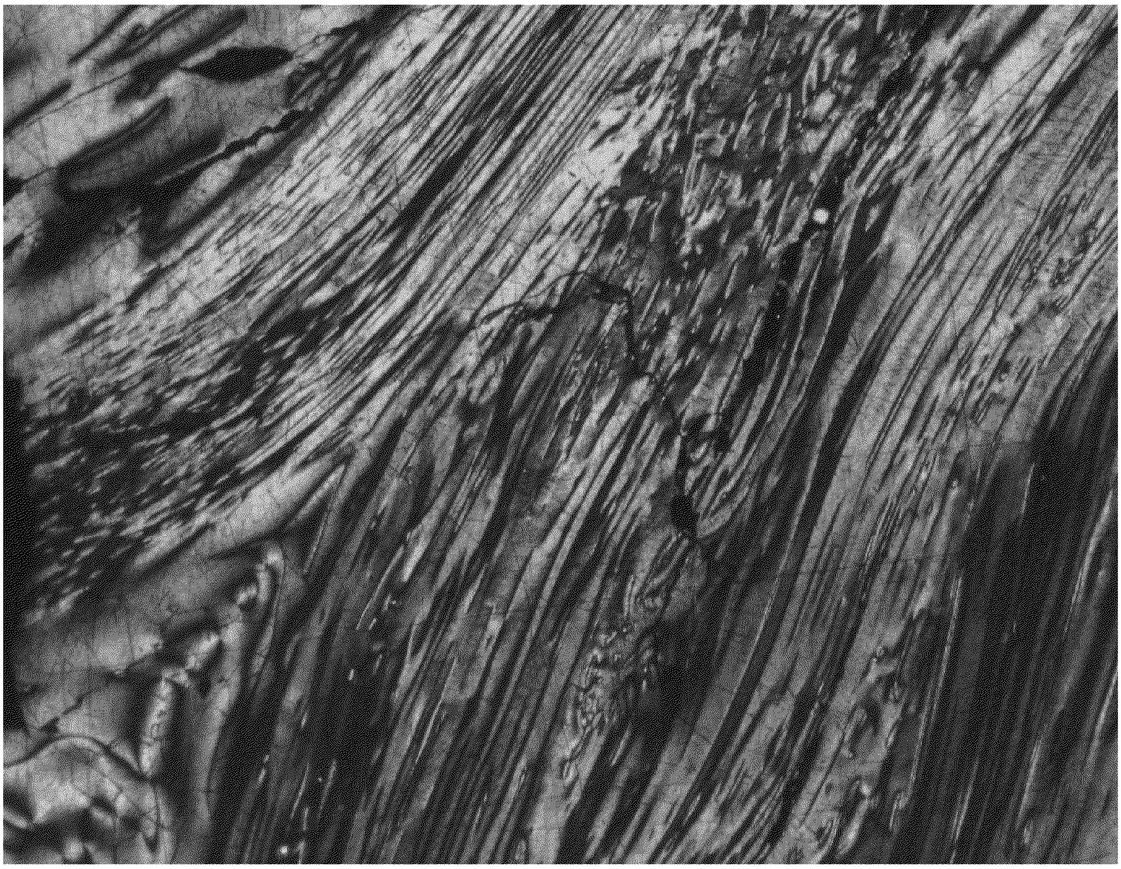

Fig. 7

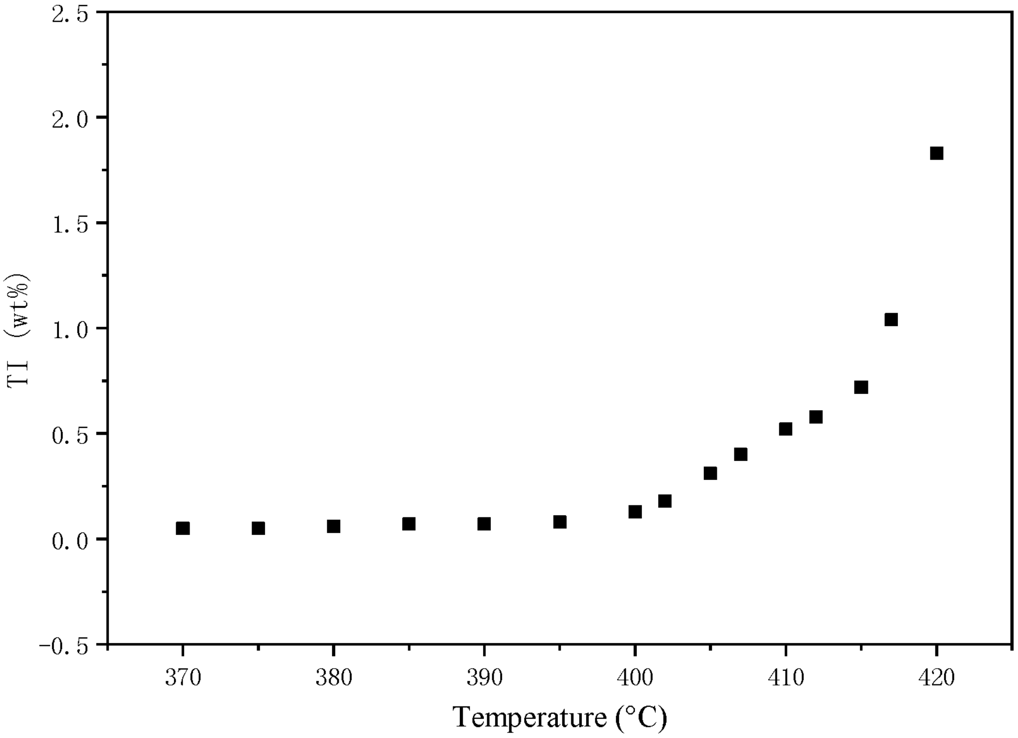

Fig. 8

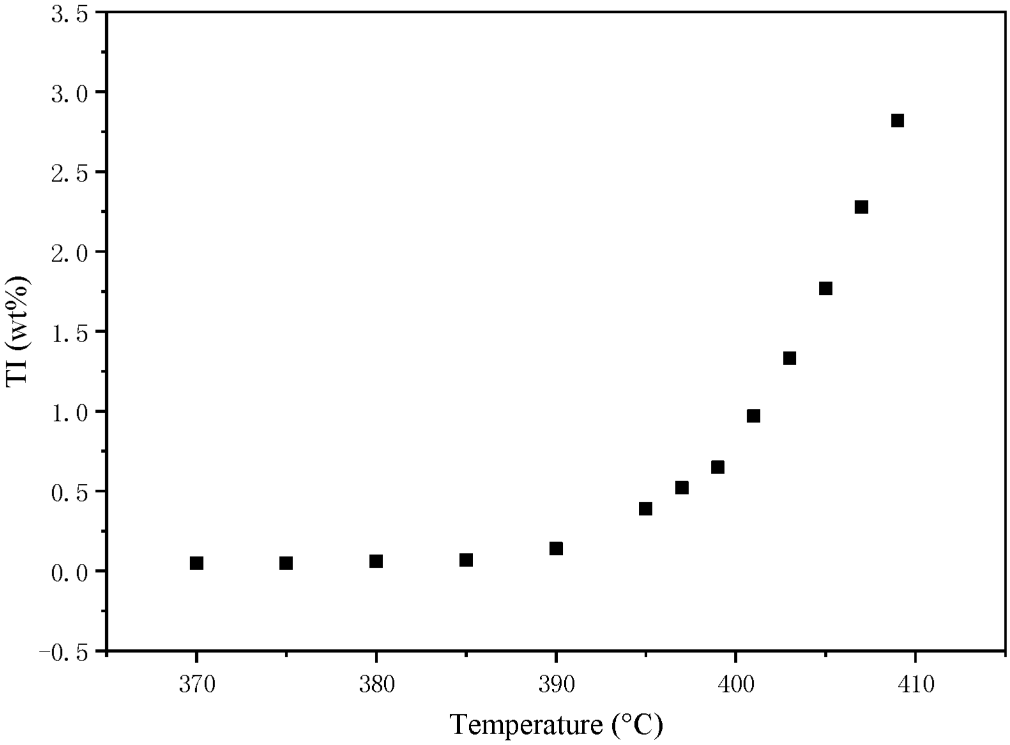

Fig. 9

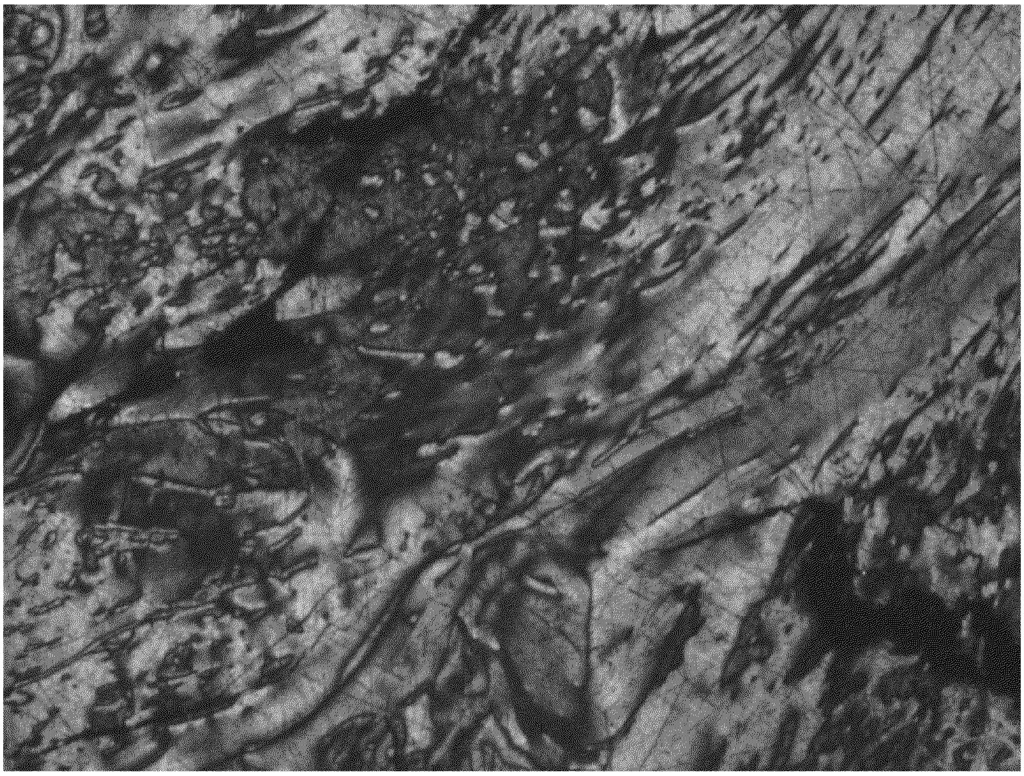

Fig. 10

Fig. 11

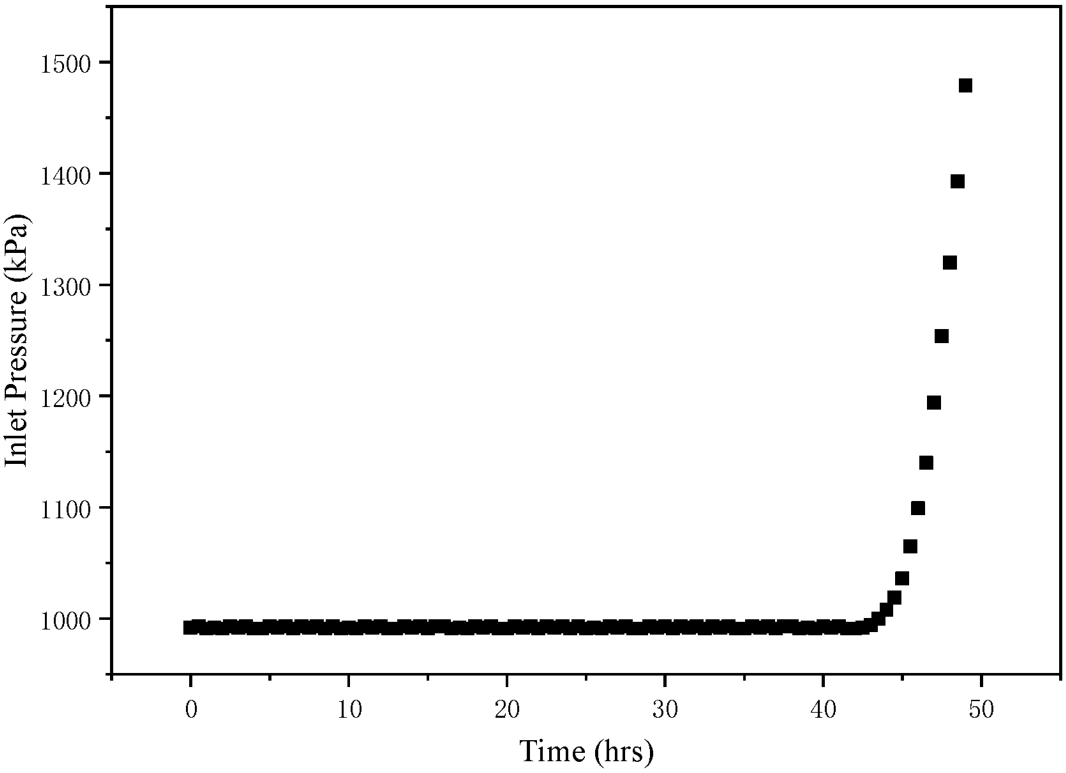
Inlet Pressure (kPa)
1500
1400
1300
1200
1100
1000
0
10
20
30
40
50
Time (hrs)

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/098775

A. CLASSIFICATION OF SUBJECT MATTER

C10B55/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT; VEN; CJFD: 针状焦, 乙烯焦油, 催化油浆, 加氢, 裂化, 萃取, needle coke, ethylene tar, decant oil, hydrogeneration, crack, extract

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 107987880 A (CHINA PETROLEUM & CHEMICAL CORP. et al.) 04 May 2018 (2018-05-04) description, paragraphs 5-19	1-24
A	CN 113122330 A (CHINA PETROLEUM & CHEMICAL CORP. et al.) 16 July 2021 (2021-07-16) entire document	1-24
A	CA 2733271 A1 (THE MINISTER OF NATURAL RESOURCES CANADA) 18 February 2010 (2010-02-18) entire document	1-24

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A"	document defining the general state of the art which is not considered to be of particular relevance
"D"	document cited by the applicant in the international application
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search **11 August 2023**	Date of mailing of the international search report **09 September 2023**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/098775

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 107987880 A	04 May 2018	None	
CN 113122330 A	16 July 2021	None	
CA 2733271 A1	18 February 2010	CA 2733271 C	16 July 2013
		US 2010032347 A1	11 February 2010
		EP 2318484 A1	11 May 2011
		EP 2318484 A4	21 December 2011
		WO 2010017618 A1	18 February 2010

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REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- CN 110511785 A **[0003]**
- CN 103102974 A **[0004]**