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(54) PROCESS FOR THE PURIFICATION OF A CRUDE PYROLYSIS PRODUCT

(57) The invention relates to a process for the purification of a crude pyrolysis product, the process comprising the steps of A1) providing a crude pyrolysis product, the crude pyrolysis product comprising hydrocarbons and impurities, the crude pyrolysis product at least partially originating from pyrolysis of plastic waste, A2) bringing the crude pyrolysis product into contact with alkali hydroxide at a temperature of from 330 to 400 °C, preferably 340 to 360 °C, in a continuous mode with a residence time of less than 10 min to obtain a treated pyrolysis product and a residue comprising reacted impurities, A3) washing the treated pyrolysis product with a polar washing solvent to obtain a purified pyrolysis product and a polar washing solvent phase, A4) separating the polar washing solvent phase from the purified pyrolysis product.

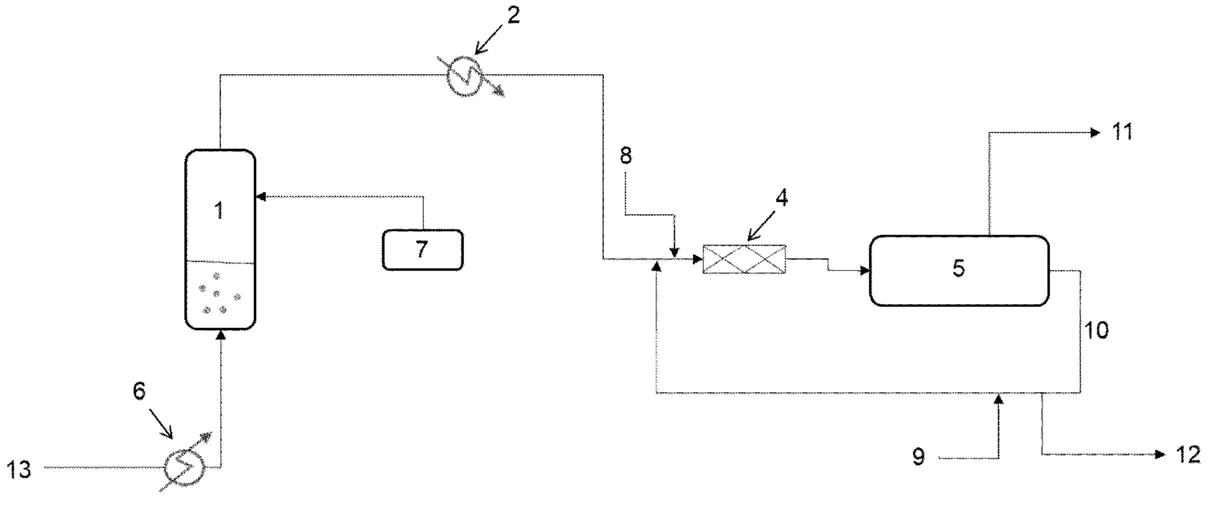

Figure 1

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Description

[0001] The present invention relates to a process for the purification of a crude pyrolysis product, the crude pyrolysis product preferably at least partially originating from the pyrolysis of plastic waste, to obtain a purified pyrolysis product. The invention is further directed to a method for producing a cracker feedstock, particularly a steam cracker feedstock, comprising the purified pyrolysis product.

[0002] Pyrolysis is an important technique for chemically recycling e.g. plastic waste. The pyrolysis is generally a thermal degradation of feedstock in an inert atmosphere and yields value added products such as pyrolysis gas, liquid pyrolysis oil and char (residue), wherein pyrolysis oil containing hydrocarbons is the major product.

[0003] Dependent on the type and quality of feedstock used for the preparation of pyrolysis oil, a broad range of impurities can typically be found in the pyrolysis oil. Typical feedstock for the preparation of pyrolysis oil is plastic waste, but also biomass may be used. Pyrolysis oil produced from plastic waste contains more and other contaminants than fossil feedstock whereas plastics are used for a wide variety of applications and therefore contains a wide variety of different additives. Such impurities found in the pyrolysis oil are for example inorganic compounds, such as metal-containing compounds and complexes, and organic compounds containing heteroatoms, such as nitrogen, oxygen, sulphur, silicon, and halogens, particularly chlorine. The pyrolysis oil might also have generally higher content of unsaturated hydrocarbon compounds, such as olefins, than fossil feedstock. Low concentrations of these impurities, particularly chlorine-containing compounds and diolefins, is for instance of high importance for avoiding problems during storage and processing of the pyrolysis oil, including for use as (steam) cracker feedstock in base chemical production such as ethylene and propylene. Otherwise, the impurities can lead to problems in the further processing or use of the pyrolysis oil, such as sedimentation and gum formation, deactivation/poisoning of catalysts, formation of deposits and corrosion of lines and reactors. Steam cracking of untreated plastic waste pyrolysis oils is for example discussed by Kusenberg et al, "Assessing the feasibility of chemical recycling via steam cracking of untreated plastic waste pyrolysis oils: Feedstock impurities, product yields and coke formation", Waste Management, vol 141, pages 104-114 (2022), where the authors conclude that purification of the pyrolysis oil prior to steam cracking is a prerequisite to avoid operational issues resulting from increased coke formation and fouling.

[0004] In accordance with Kusenberg et al, "Opportunities and challenges for the application of post-consumer plastic waste pyrolysis oil as steam cracker feedstock: To decontaminate or not to decontaminate?", Waste Management, vol. 148, pages 83-115 (2022), a typical steam cracker feedstock for base chemical production may include not more than 3 ppm chlorine, not more than 100 ppm nitrogen, and not more than 100 ppm oxygen.

[0005] For being able to meet the high purity standards that are required for the use of these pyrolysis oils, for example as steam cracker feedstock for base chemical production, typically dilution with fossil naphtha and/or purification of the pyrolysis oil is required. Purification of crude pyrolysis oil can for example be done by a costly hydrotreatment step or simply by a washing step, i.e. by extracting the impurities with a solvent that is immiscible with the oil. However, even if such a washing step can be efficient for the removal of polar impurities, only a low removal efficiency can be found in case of non-polar impurities with a high solubility in the oil, e.g. certain organic chlorides.

[0006] Generally, pyrolysis oil at least partially originating from the pyrolysis of plastic waste requires dehalogenation (particularly dechlorination), denitrogenation and deoxygenation to reduce the concentrations of these impurities and allow use in cracker feedstock, such as steam cracker feedstock.

[0007] WO 2022/234225 A1 discloses a method for purifying a hydrocarbon charge in the presence of a solvent. This document describes a caustic treatment purification process using a base and a polar component with alcohol or ether function. The contact or residence time in the reactor for bringing the pyrolysis oil into contact with the base and a polar component with alcohol or ether function can be up to 48 hours.

[0008] However, upon scaling up a high-temperature reactive extraction process to commercial scale, achieving short residence times becomes problematic. The reason is that with increasing reactor size, heat transfer efficiency has to be reconsidered and the ratio of the heating surface area to the batch volume is reduced making the heating and cooling processes slow. In addition, in commercial plants all required heating and cooling times are considered as wasted time and thus detrimental for optimal operational process efficiency.

[0009] It is an object of the present invention to provide a process for purifying a crude pyrolysis product originating from the pyrolysis of a feedstock, in particular purifying a crude pyrolysis product having various impurities.

[0010] It is a further object of the present invention to provide a process for purifying a crude pyrolysis product at least partially originating from the pyrolysis of plastic waste having an improved removal efficiency for impurities present in the crude pyrolysis product.

[0011] It is a further object of the present invention to provide a process for purifying a crude pyrolysis product having short residence times and at the same time having an improved removal efficiency for impurities present in the crude pyrolysis product.

[0012] It is a further object of the present invention to provide a purified pyrolysis product, which meets the standards for use as cracker feedstock (alone or diluted with fossil naphtha) in base chemical production. As used herein, "cracker feedstock" refers to a feedstock suitable for steam cracking, hydrocracking or catalytic cracking. More particularly, an object of the invention is to obtain a cracker feedstock that meets the requirements for use as feedstock (alone or diluted with fossil naphtha) in a steam cracker.

[0013] To solve all the above objects, the present invention provides a process for the purification of a crude pyrolysis product, the process comprising the steps of

A1) providing a crude pyrolysis product, the crude pyrolysis product comprising hydrocarbons and impurities, the crude pyrolysis product at least partially originating from pyrolysis of plastic waste,

A2) bringing the crude pyrolysis product into contact with alkali hydroxide at a temperature of from 330 to 400 °C, preferably 340 to 360 °C, in a continuous mode with a residence time of less than 10 min to obtain a treated pyrolysis product and a residue comprising reacted impurities,

A3) washing the treated pyrolysis product with a polar washing solvent to obtain a purified pyrolysis product and a polar washing solvent phase,

A4) separating the polar washing solvent phase from the purified pyrolysis product obtained in step A3).

[0014] The present invention provides a purified pyrolysis product having reduced nitrogen and halogen content in relation to the crude pyrolysis product, particularly a purified pyrolysis product having reduced nitrogen, halogen, and sulphur contents in relation to the crude pyrolysis product. A further advantage of the present invention is that the provided purified pyrolysis product may have reduced content of olefins in relation to the crude pyrolysis oil.

[0015] Still a further advantage is that the process for the purification of a crude pyrolysis product according to the invention enables a high temperature treatment in continuous mode. This allows a shorter residence time and thus more efficient operation of the overall purification process.

[0016] A still further advantage of the purification process of the invention is that an increase of the final boiling point of the pyrolysis product due to the high temperature treatment is kept as low as possible. An increase of the final boiling point of a purified pyrolysis oil is generally an undesired effect as it affects the quality of the purified pyrolysis oil. The reason is that purified pyrolysis oils obtained from plastic wastes are often used as feedstock for the steam crackers. For steam crackers the accepted final boiling point should be as low as possible, such as below 400 °C.

[0017] The present invention thus synergistically provides the advantages of a high temperature treatment in continuous mode, allowing shorter residence time and at the same time keeping the increase of the final boiling point of the pyrolysis product as low as possible.

[0018] As used herein, the term "olefins" refers to unsaturated open-chain (linear) hydrocarbons.

[0019] As used herein, the term "hydrocarbon" refers to organic compounds consisting of carbon and hydrogen.

[0020] In step A1) of the process according to the invention a crude pyrolysis product is provided. The crude pyrolysis product comprises hydrocarbons and impurities and the crude pyrolysis product at least partially originates from pyrolysis of plastic waste. Preferably, the crude pyrolysis product is a crude plastic waste pyrolysis product.

[0021] In the present invention, the term "pyrolysis" relates to a thermal decomposition or degradation of a feedstock, such as end of life plastics (plastic waste) or plastic waste combined with biomass, under inert conditions and results in a gas, a liquid and a solid char fraction. During pyrolysis of plastic waste, the plastics are converted into a great variety of chemicals including gases such as H_2, C1-C4-alkanes, C2-C4-alkenes, acetylene, propyne, 1-butyne, pyrolysis oil having a boiling temperature of 25 to 500 °C, or even 600 °C, and char.

[0022] The term "pyrolysis" includes slow pyrolysis, fast pyrolysis, flash catalysis and catalytic pyrolysis. These type of pyrolysis differ in the process temperature, heating rate, residence time, feed particle size, etc. resulting in different product quality. Sharuddin et al, "A review of pyrolysis of plastic waste", Energy Conversion and Management, vol. 115, pages 308-326 (May 2016) describes typical process conditions for pyrolysis of plastic waste.

[0023] In the context of the present invention, the term "crude pyrolysis product" is understood to mean any product at least partially originating from the pyrolysis of plastic waste, including (i) any crude pyrolysis product fully originating from the pyrolysis of plastic waste (herein referred to as "crude plastic waste pyrolysis product"), (ii) any crude pyrolysis product originating from the pyrolysis of a mixture of plastic waste and biomass, or (iii) any crude pyrolysis product comprising a mixture of crude plastic waste pyrolysis product and crude biomass pyrolysis product.

[0024] As used herein, "crude plastic waste pyrolysis product" means pyrolysis product derived from pyrolysis of a feedstock consisting of plastic waste.

[0025] As used herein, "crude biomass pyrolysis product" means pyrolysis product derived from pyrolysis of a feedstock consisting of biomass.

[0026] As used herein, the term "pyrolysis product" generally encompasses a pyrolysis gas, a pyrolysis oil and/or char (residue). In other words, the pyrolysis product may be present in the form of a pyrolysis gas, i.e. in the gaseous phase, and/or in the form of a pyrolysis oil, i.e. in the liquid phase, and/or as char, i.e. in the solid phase.

[0027] The term "pyrolysis gas" is herein also referred to as "pyrolysis product in the gaseous phase". Both the term "liquid pyrolysis oil" and the term "pyrolysis oil" are herein also referred to as "pyrolysis product in the liquid phase".

[0028] The crude pyrolysis oil, i.e. the crude pyrolysis product in the liquid phase, typically is a liquid at 15 °C and 1013 mbar. The term "liquid at 15 °C" means that the crude pyrolysis oil has a dynamic viscosity in the range of from 0.1 to 100 mPa • s as determined by ASTM D7042, for example using Viscometer SVM3000.

[0029] Depending on the plastic waste subjected to the pyrolysis, the crude pyrolysis product may have varying contents of sulphur, nitrogen, halogen, oxygen and, if present, heavy metal. There are very many different qualities of crude pyrolysis product derived from varying compositions of plastic waste which means that the content and types of impurities may vary significantly.

[0030] The crude pyrolysis product generally contains saturated hydrocarbon compounds, unsaturated hydrocarbon compounds (olefins) and organic or inorganic compounds comprising at least one heteroatom selected from oxygen, sulphur, nitrogen and halogens, particularly organic or inorganic compounds comprising two or more heteroatoms selected from oxygen, sulphur, nitrogen and halogens. The crude pyrolysis product typically contains sulphur-containing compounds, nitrogen-containing compounds, oxygen-containing compounds and halogen-containing compounds. The crude pyrolysis oil might also contain cyclic hydrocarbon molecule structures like naphthenes and aromatics.

[0031] In a specific embodiment, the crude pyrolysis product is a nitrogen-containing and halogen-containing crude plastic waste pyrolysis product, particularly a nitrogen-containing, halogen-containing and sulphur-containing crude plastic waste pyrolysis product, and more particularly a nitrogen-containing, halogen-containing, oxygen-containing and sulphur-containing crude plastic waste pyrolysis product.

[0032] In one embodiment, the crude pyrolysis product has a sulphur content of 10 mg/l or more, such as 50 mg/l or more, or 100 mg/l or more; or 500 mg/l or more, relative to the total volume of the crude pyrolysis product. In another embodiment, the crude pyrolysis product has a sulphur content of 100 to 5000 mg/l, often 500 to 4000 mg/l, relative to the total volume of the crude pyrolysis product.

[0033] In another embodiment, the crude pyrolysis product has a sulphur content of at least 10 mg/l but not more than 100 mg/l, such as within the range from 10 mg/l to 50 mg/l, or from 10 mg/l to 30 mg/l, relative to the total volume of the crude pyrolysis product.

[0034] In one embodiment, the crude pyrolysis product has a nitrogen content of 50 mg/l or more, such as 100 mg/l or more; or 500 mg/l or more; or 2000 mg/l or more, relative to the total volume of the crude pyrolysis product. In another embodiment, the crude pyrolysis product has a nitrogen content of 800 to 4000 mg/l, often 900 to 3000 mg/l, relative to the total volume of the crude pyrolysis product.

[0035] In one embodiment, the crude pyrolysis product has a halogen content of 10 mg/l or more, such as 20 mg/l or more; such as 80 mg/l or more; or 120 mg/l or more; or 400 mg/l or more; or 600 mg/l or more, relative to the total volume of the crude pyrolysis product. In another embodiment, the crude pyrolysis product has a halogen content of 100 to 1000 mg/l, often 120 to 900 mg/l, relative to the total volume of the crude pyrolysis product.

[0036] When the density of the pyrolysis oil is about 1 g/ml (1000 kg/m^3), the above concentrations given in mg/l equals the same concentrations in ppm, i.e. 1 mg/l then equals 1 ppm.

[0037] Organofluorine, organochlorine, organobromine and/or organoiodine compounds typically are the source for the halogen content in the crude pyrolysis product. Specifically, the halogen content is a bromine and chlorine content to 90% or more, such as 95% or more or even 100%. More specifically, the halogen content is to 90% or more, such as 95% or more or even 100% a chlorine content. Thus, the crude pyrolysis product may have a chlorine content of 10 mg/l or more, such as 20 mg/l or more, relative to the total volume of the crude pyrolysis product.

[0038] In one embodiment, the crude pyrolysis product has an oxygen content of 40 mg/l or more, such as 80 mg/l or more; or 120 mg/l or more; or 400 mg/l or more; or 600 mg/l or more, relative to the total volume of the crude pyrolysis product. In another embodiment, the crude pyrolysis product has an oxygen content of 100 to 5000 mg/l, often 120 to 2000 mg/l, relative to the total volume of the crude pyrolysis product.

[0039] In case that the crude pyrolysis product also has a heavy metal content, the heavy metal content is at least 1 mg/l, relative to the total volume of the crude pyrolysis product. In one embodiment, the crude pyrolysis product has a heavy content of 5 mg/l to 15 mg/l, or 5 to 20 mg/l relative to the total volume of the crude pyrolysis product.

[0040] As used herein, the term "heavy metal" refers to a metal or metalloid having a density >4.51 g/cm^3 (at 20 °C). Examples of heavy metals include arsenic, antimony, bismuth, selenium, tin, cadmium, chromium, copper, mercury, nickel and lead.

[0041] Two or more of the above described embodiments of the crude pyrolysis product as regards its sulphur, nitrogen, halogen, oxygen, and heavy metal content can be combined in any manner. For example, the crude pyrolysis product may preferably have a nitrogen content as described above, a halogen content as described above and a sulphur content as described above.

[0042] In an embodiment, the crude pyrolysis product has a sulphur content of 10 mg/l or more, a nitrogen content of 50 mg/l or more, such as 200 mg/l or more, and a chlorine content of 10 mg/l or more. More particularly, the crude pyrolysis product has a sulphur content within the range of from 10 mg/l to 50 mg/l (for example, within the range of from 10 mg/l to 30 mg/l), a nitrogen content of 200 mg/l or more, and a chlorine content of 10 mg/l or more.

[0043] In another embodiment, the crude pyrolysis product has an oxygen content of 40 mg/l or more, a sulphur content of 10 mg/l or more, a nitrogen content of 50 mg/l or more, and a chlorine content of 10 mg/l or more.

[0044] In another embodiment, the crude pyrolysis product has an oxygen content of 40 mg/l or more, a sulphur content of 10 mg/l or more, a nitrogen content of 50 mg/l or more, a chlorine content of 10 mg/l or more and an olefin content of 30 wt.% or more based on the total weight of the crude pyrolysis product.

[0045] The process according to the invention may provide purified pyrolysis oil having the nitrogen content reduced by 10 to 95%, such as at least 50% or at least 60% or at least 70%, relative to the nitrogen content of the crude pyrolysis product.

[0046] The process according to the invention may provide purified pyrolysis product having the chlorine content reduced by 10 to 95%, such as at least 50% or at least 60% or at least 70% or at least 80% or at least 90%, relative to the chlorine content of the crude pyrolysis product.

[0047] Normally, the pyrolysis product comprises paraffins, such as n-paraffins and/or i-paraffins, olefins, naphthenes and/or aromatics. The crude pyrolysis oil originating from plastic waste is further characterized by, but not limited to

a boiling point in the range of from 30 to 600 °C as determined by ASTM D2887, and/or

a dynamic viscosity in the range of from 0.1 to 100 mPa • s as determined by ASTM D7042, for example using Viscometer SVM3000, and/or

a total paraffin content in the range of from 5 to 80 wt.%, or 15 to 70 wt.%, or 20 to 65 wt.%, based on the total weight of the crude pyrolysis oil, as determined by GC×GC-FID/MS or GC-MS and GC-FID, and/or

a n-paraffin content in the range of from 20 to 80 wt.%, based on the total weight of the crude pyrolysis oil, as determined by GC×GC-FID/MS or GC-MS and GC-FID, and/or

an i-paraffin content in the range of from 2 to 80 wt.%, or 5 to 60 wt.%, or 10 to 45 wt.%, based on the total weight of the crude pyrolysis oil, as determined by GC×GC-FID/MS or GC-MS and GC-FID, and/or

an olefin content in the range of from 0 to 70 wt.%, or 15 to 65 wt.%, or 20 to 60 wt.%, based on the total weight of the crude pyrolysis oil, as determined by GC×GC-FID/MS or GC-MS and GC-FID, and/or

a naphthene content in the range of from 0 to 50 wt.%, or 5 to 45 wt.%, or 10 to 40 wt.%, based on the total weight of the crude pyrolysis oil, as determined by GC×GC-FID/MS or GC-MS and GC-FID, and/or

an aromatic content in the range of from 0 to 50 wt.%, or 5 to 30 wt.%, or 10 to 25 wt.%, based on the total weight of the crude pyrolysis oil, as determined by GC×GC-FID/MS or GC-MS and GC-FID, and/or

a density in the range from 600 kg/m^3 to 1 200 kg/m^3, at 15 °C and 1013 mbar, as determined according to DIN EN ISO 12185.

[0048] The above further characteristics or properties of the crude pyrolysis oil originating from plastic waste can be combined with each other in any way or they can be combined in any way with other characteristics or properties of the crude pyrolysis oil originating from plastic waste disclosed herein.

[0049] The feedstock for the pyrolysis is typically plastic waste or plastic waste combined with biomass.

[0050] As used herein, the term "plastic waste" refers to any plastic or rubber material discarded after use, i.e. the plastic material has reached the end of its useful life. The plastic waste can be pure polymeric plastic waste, mixed plastic waste or film waste, including soiling, adhesive materials, fillers, residues etc. The plastic waste may have a nitrogen content, sulphur content, halogen content, oxygen content, silicon and optionally also a heavy metal content. The plastic waste can originate from any plastic material containing source. Accordingly the term "plastic waste" includes industrial and domestic plastic waste including used tires and agricultural and horticultural plastic material. The term "plastic waste" may also include used petroleum-based hydrocarbon material such as used motor oil, machine oil, greases, waxes, etc. Preferably, the plastic waste essentially consists of plastic and/or rubber materials.

[0051] Typically, plastic waste is a mixture of different plastic material, including hydrocarbon plastics, e.g., polyolefins such as polyethylene (HDPE, LDPE) and polypropylene, polystyrene and copolymers thereof, etc., and polymers composed of carbon, hydrogen and other elements such as chlorine, fluorine, oxygen, nitrogen, sulphur, silicon, etc., for example chlorinated plastics, such as polyvinylchloride (PVC), polyvinylidene chloride (PVDC), etc., nitrogen-containing plastics, such as polyamides (PA), polyurethanes (PU), acrylonitrile butadiene styrene (ABS), etc., oxygen-containing plastics such as polyesters, e.g. polyethylene terephthalate (PET), polycarbonate (PC), etc., silicones and/or sulphur bridged crosslinked rubbers. PET plastic waste is often sorted out before pyrolysis, since PET has a profitable resale value. Accordingly, the plastic waste to be pyrolyzed often contains less than about 10 wt.%, preferably less than about 5 wt.% and most preferably substantially no PET based on the dry weight of the plastic material. As used herein, "biomass" refers to any plant or animal based material such as wood residues, lignocellulosic biomass, paper, cardboard, energy crops, agricultural residues, and food waste from industry, households and farms.

[0052] Haoxi et al, "A comprehensive Characterization of Pyrolysis Oil from Softwood Barks", Polymers 2019, 11, 1387, provides an example of crude pyrolysis oil derived from pyrolysis of biomass.

[0053] The process according to the invention comprises three preferred embodiments. In a first embodiment the crude pyrolysis product is substantially in gaseous phase, in a second embodiment the crude pyrolysis product is substantially in liquid phase and in a third embodiment a first part of the crude pyrolysis product is in gaseous phase and a second part of the crude pyrolysis product is in liquid phase.

[0054] In the first embodiment of the invention the crude pyrolysis product is substantially in gaseous phase, and step A2) comprises bringing the crude pyrolysis product into contact with molten alkali hydroxide in a reactor at a temperature of from 330 to 400 °C for a residence time of from 0.5 to less than 10 min in a continuous mode to obtain a treated pyrolysis product.

[0055] As used herein, the term "substantially in gaseous phase" means that at least 95 wt.%, preferably at least 98 wt.%, preferably at least 99 wt.%, more preferably at least 99.9 wt.% and most preferably 100 wt.% of the crude pyrolysis product are in the gas phase, based on the total weight of the crude pyrolysis product.

[0056] As used herein, the term "in a continuous mode" means that fresh reactants, i.e. fresh feed of alkali hydroxide and fresh feed of crude pyrolysis product, are continuously brought into contact with each other. This is in contrast to a batch operation which operates in a non-continuous mode.

[0057] Preferably the residence time in step A2) of the first embodiment is of from 0.5 to less than 5 min, more preferably of from 0.5 to less than 1 min.

[0058] Preferably the temperature in step A2) of the first embodiment is of from 340 to 360 °C.

[0059] Preferably a weight ratio between the crude pyrolysis product and the solid alkali hydroxide in step A2) of the first embodiment is from 10:1 to 1000:1, more preferably 50:1 to 50:1.

[0060] Step A2) of the first embodiment preferably further comprises cooling the treated pyrolysis product. Preferably, the treated pyrolysis product is cooled in a heat exchanger and/or the treated pyrolysis product is cooled to a temperature of from 25 to 100 °C, more preferably of from 35 to 70 °C.

[0061] In the second embodiment of the invention the crude pyrolysis product is substantially in liquid phase, and step A2) comprises bringing the crude pyrolysis product into contact with solid alkali hydroxide, preferably in a continuous mode, in a mixing unit and heating with a heating apparatus to a temperature of from 330 to 400 °C, preferably at a pressure in the heating apparatus of from 0.5 to 50 bar, in a continuous mode for a residence time of from 0.5 to less than 10 min.

[0062] The term "substantially in liquid phase" means that that at least 95 wt.%, preferably at least 98 wt.%, preferably at least 99 wt.%, most preferably at least 99.9 wt.% of the crude pyrolysis product are in the liquid phase, based on the total weight of the crude pyrolysis product.

[0063] Preferably the residence time in step A2) of the second embodiment is of from 0.5 to less than 5 min, more preferably of from 0.5 to less than 1 min.

[0064] Preferably the temperature in step A2) of the second embodiment is of from 340 to 360 °C.

[0065] Preferably a weight ratio between the crude pyrolysis product and the solid alkali hydroxide in step A2) of the second embodiment is from 10:1 to 1000:1, more preferably 50:1 to 500:1.

[0066] Step A2) of the second embodiment preferably further comprises cooling the treated pyrolysis product. Preferably, the treated pyrolysis product is cooled in a heat exchanger and/or the treated pyrolysis product is cooled to a temperature of from 25 to 100 °C, more preferably of from 35 to 70 °C.

[0067] In the third embodiment of the invention a first part of the crude pyrolysis product is in gaseous phase and a second part of the crude pyrolysis product is in liquid phase, and step A2) comprises bringing the first part of the crude pyrolysis product into contact with molten alkali hydroxide in a reactor at a temperature of from 330 to 400 °C, preferably 340 to 360 °C, for a residence time of from 0.5 to less than 10 min in a continuous mode to obtain a first treated pyrolysis product,

> and step A2) further comprises bringing the second part of the crude pyrolysis product into contact with solid alkali hydroxide in a mixing unit and heating with a heating apparatus to a temperature of from 330 to 400 °C, preferably 340 to 360 °C, in a continuous mode for a residence time of from 0.5 to less than 10 min, to obtain a second treated pyrolysis product,
>
> the process further comprising step A2a) of combining the first treated pyrolysis product and the second treated

pyrolysis product to obtain a combined treated pyrolysis product, optionally cooling the combined treated pyrolysis product obtained in step A2a) to obtain a cooled combined treated pyrolysis product,

wherein step A3) comprises washing the cooled combined treated pyrolysis product obtained in step A2a), or the optionally cooled combined treated pyrolysis product obtained in step A2a), with the polar washing solvent.

[0068] Preferably the weight ratio between the first part of the crude pyrolysis product and the molten alkali hydroxide is from 10:1 to 1000:1, more preferably 50:1 to 500:1.

[0069] Preferably the weight ratio between the second part of the crude pyrolysis product and the solid alkali hydroxide is from 10:1 to 1000:1, more preferably 50:1 to 500:1.

[0070] Preferably, step A2) of the third embodiment of the invention further comprises cooling the first treated pyrolysis product and/or cooling the second treated pyrolysis product.

[0071] Preferably, cooling the first treated pyrolysis product takes place in a heat exchanger and/or cooling the first treated pyrolysis product to a temperature of from 25 to 100 °C, and/or cooling the second treated pyrolysis product takes place in a heat exchanger and/or cooling the second treated pyrolysis product to a temperature of from 25 to 100 °C.

[0072] In the following, preferred features of the first, second and third embodiment of the invention are described. Unless stated otherwise, the following preferred features are preferred features of the first, second and third embodiment of the invention, if applicable.

[0073] In the first and the third embodiments of the process according to the invention, the reactor in step A2) is preferably a bubble column reactor.

[0074] A bubble column reactor is a vertical cylinder to which gas is fed from the bottom through a gas sparger or, for example, a porous plate distributor to minimize the bubble size of the gas. The bubble column works as a multi-phase reactor, where the gas phase is dispersed in the liquid phase. The liquid phase comprising or consisting of the molten alkali hydroxide can be supplied for instance counter currently to the upward flowing gas stream. The gas comprises, or consists of, the crude pyrolysis product being substantially in gaseous phase and is fed, preferably continuously fed, to the bubble column reactor.

[0075] Preferably the reactor in step A2) further comprises heating means for controlling the heat in the reactor, the reactor preferably being a bubble column reactor. Preferably the heating means comprise microwaves and/or electric heating.

[0076] In the second and the third embodiments of the process according to the invention, the mixing unit in step A2) can be any mixing unit suitable for mixing, preferably continuously mixing, the pyrolysis product with solid alkali hydroxide. Preferably the mixing unit in step A2) is a homogenizing pump.

[0077] In the second and the third embodiments of the process according to the invention, the heating apparatus in step A2) is preferably a heat exchanger, preferably the heat exchanger being a tube heat exchanger, preferably the heat exchanger being an electrically heated or a fired heat exchanger or an electrically heated or a fired tube heat exchanger. Preferably, the pressure in the heating apparatus in step A2) is of from 0.5 to 50 bar. In case the heating apparatus is a fired heat exchanger, the pressure in the fired heat exchanger is of from 1 bar to below 10 bar.

[0078] Preferably, the alkali hydroxide of step A2) comprises, or consists of, sodium hydroxide, potassium hydroxide or mixtures thereof, more preferably comprises, or consists of, sodium hydroxide.

[0079] In the first embodiment of the invention, the provided crude pyrolysis product is substantially in gaseous phase. This is, for example, the case if the crude pyrolysis product is directly provided from the pyrolysis reactor. However, should the provided crude pyrolysis product not be substantially in gaseous phase, preheating is needed to bring also the remaining liquid parts of the crude pyrolysis product into the gas phase. Preferably, in the first embodiment of the invention the crude pyrolysis product provided in step A1) is pre-heated to a temperature within the range of from 330 to 400 °C, preferably 340 to 360 °C, prior to step A2).

[0080] In the third embodiment of the invention, a first part of the provided crude pyrolysis product is substantially in gaseous phase and a second part of the provided crude pyrolysis oil is in liquid phase. In case it is desired that a larger part of the provided crude pyrolysis shall be in the gaseous phase, a pre-heating step is needed. Preferably, in the third embodiment of the invention the first part of the crude pyrolysis product provided in step A1) is pre-heated to a temperature within the range of from 330 to 400 °C, preferably 340 to 360 °C, prior to step A2).

[0081] Pre-heating is preferably done by a heat exchanger, the heat exchanger preferably being an electrically heated heat exchanger or a fired heat exchanger.

[0082] In step A3) the treated pyrolysis product is washed with a polar washing solvent to obtain a purified pyrolysis product and a polar washing solvent phase. The washing step removes remaining alkali hydroxide as well as organic products formed in the reaction between the crude pyrolysis product and the alkali hydroxide during step A2).

[0083] Preferably, step A3) is carried out in a mixing device. The mixing device is preferably a mixer or a static mixer.

[0084] Preferably, the polar washing solvent of step A3) comprises, or consists of, water, an alkanol or a mixture thereof, more preferably comprises, or consists of, water.

[0085] Preferably, in step A3) the polar washing solvent further comprises an acid. An acid is preferably present in case step A3) shall be carried out as a neutralization wash, i.e. to neutralize any remaining alkali hydroxide. Preferably the acid comprises, or consists of, sulphuric acid, hydrochloric acid or phosphoric acid, more preferably the acid comprises, or consists of, sulphuric acid.

[0086] In step A4) the polar washing solvent phase is separated from the purified pyrolysis product. Preferably, step A4) is carried in a separation device. The separation device is preferably a settler tank or a mixer-settler system, more preferably a mixer-settler system.

[0087] The invention further provides a method for producing a cracker feedstock comprising the step of blending 1 to 100 wt.% of a purified pyrolysis oil based on the total weight of the cracker feedstock and 0 to 99 wt.% of fossil naphtha based on the total weight of the cracker feedstock, wherein the purified pyrolysis oil is obtained by the process according to the invention.

[0088] All preferred embodiments of the process for the purification of a crude pyrolysis oil according to the invention are also preferred embodiments of the method for producing a cracker feedstock, if applicable.

[0089] Preferably, the cracker feedstock is a steam cracker feedstock.

[0090] In an embodiment, the cracker feedstock, or the steam cracker feedstock, comprises at least 5 wt.% of the purified pyrolysis oil and not more than 95 wt.% of fossil naphtha based on the total weight of the cracker feedstock, preferably the cracker feedstock, or the steam cracker feedstock, comprises at least 10 wt.% of the purified pyrolysis oil and not more than 90 wt.% of fossil naphtha based on the total weight of the cracker feedstock, more preferably the cracker feedstock, or the steam cracker feedstock, comprises at least 30 wt.% of the purified pyrolysis oil based on the total weight of the cracker feedstock and not more than 70 wt.% of fossil naphtha based on the total weight of the cracker feedstock, particularly the cracker feedstock, or the steam cracker feedstock, comprises at least 40 wt.% of the purified pyrolysis oil based on the total weight of the cracker feedstock and not more than 60 wt.% of fossil naphtha based on the total weight of the cracker feedstock.

[0091] The invention further provides the use of the purified pyrolysis product as a cracker feedstock.

[0092] Preferably, the cracker feedstock is a steam cracker feedstock.

[0093] Generally, the impurities comprise inorganic compounds, the inorganic compounds preferably comprising metals or metal ions, the metals preferably being heavy metals and the metal ions being preferably heavy metal ions, and/or organic compounds containing heteroatoms, the heteroatoms preferably being oxygen, nitrogen, sulphur, silicon and/or a halogen.

[0094] The invention is further described and illustrated below by means of non-limiting examples and figures. The figures show

Figure 1 a schematic drawing of the process according to the first embodiment of the invention,

Figure 2 a schematic drawing of the process according to the second embodiment of the invention, and

Figure 3 a schematic drawing of the process according to the third embodiment of the invention.

[0095] The following reference signs are used in Figures 1 to 3:

1	reactor
2	heat exchanger
4	mixing device
5	separation device
6	preheater
7	alkali hydroxide tank with heating
8	acid feed inlet
9	polar washing solvent feed inlet
10	washing cycle line

11	purified pyrolysis product outlet
12	purge outlet
13	crude pyrolysis product feed inlet
15	pressure control valve
16	vapour-liquid separator
17	solid alkali hydroxide feed inlet
18	mixing unit
19	heating apparatus

[0096] An exemplary process falling under the first embodiment of the invention is schematically shown in Figure 1 as is described in detail below. In essence, in the first embodiment of the invention a crude pyrolysis product in the gaseous phase is provided and is brought into contact with molten alkali hydroxide at high temperatures and subsequently washed with a polar washing solvent so as to obtain a purified pyrolysis product.

[0097] A crude pyrolysis product is provided and fed via a crude pyrolysis product feed inlet (13) to a preheater (6). Typically, the preheater (6) heats the crude pyrolysis product to a temperature of from 330 to 400 °C so as to bring the crude pyrolysis product substantially in the gaseous phase before entering the reactor (1). In case the provided crude pyrolysis product is already in the gaseous phase, the optional preheater (6) is not needed and the provided crude pyrolysis product being already in the gaseous phase can be fed directly to the reactor (1). In this exemplary embodiment the reactor (1) is a bubble column reactor. The gaseous pyrolysis product is continuously introduced at the bottom of the bubble column reactor and reacts with the molten sodium hydroxide which is fed from the alkali hydroxide tank with heating. During the reaction halogens are eliminated from the pyrolysis product. The residence time of the pyrolysis product in the reactor (1) is less than 10 min and the treated pyrolysis product exits the reactor (1) and is transferred to a heat exchanger (2) in which the treated pyrolysis product is cooled to a temperature of from 25 to 100 °C.

[0098] The liquid treated pyrolysis product is subsequently combined with pure water as polar washing solvent which is introduced with polar solvent washing feed inlet (9) and washing cycle line (10). In addition, also sulphuric acid is added via acid feed inlet (8) to the liquid treated pyrolysis product to neutralize any remaining sodium hydroxide in the liquid treated pyrolysis product. The mixture of liquid treated pyrolysis product, sulphuric acid and pure water is thoroughly mixed in a mixing device (4) so as to wash and neutralize the treated pyrolysis product. In this exemplary embodiment the mixing device (4) is a static mixer. The mixture of obtained purified pyrolysis produced and the polar washing solvent phase is fed to a separation device (5) being a settling tank. In the settling tank the polar washing solvent phase comprising water and any remaining acid is separated from the purified pyrolysis product. The latter is withdrawn from the separation device (5) via purified pyrolysis product outlet (11) and the polar washing solvent phase is withdrawn via washing cycle line (10). The polar washing solvent phase can be optionally withdrawn via purge outlet (12) or mixed with fresh pure water from inlet (9) and recycled back upstream of the mixing device (4).

[0099] In Figure 2, an exemplary process falling under the second embodiment of the invention is schematically shown. In essence, in the second embodiment of the invention a crude pyrolysis product in liquid phase is provided and is brought into contact with solid alkali hydroxide at high temperatures and subsequently washed with a polar washing solvent so as to obtain a purified pyrolysis product. A crude pyrolysis product is provided in liquid form via a crude pyrolysis product feed inlet (13). The liquid crude pyrolysis product is combined with solid sodium hydroxide from solid alkali hydroxide feed inlet (17). The mixing unit (18) is in this example a homogenising pump and mixes the liquid crude pyrolysis product and solid sodium hydroxide. The resulting mixture is fed to a heating apparatus (19) being a fired heat exchanger and heated to a temperature of 330 to 400 °C. The residence time of the mixture of liquid crude pyrolysis product and solid sodium hydroxide in the heating apparatus (19) is within the range of from 0.5 to less than 10. The obtained treated pyrolysis product is withdrawn from the heating apparatus (19) and transferred to a heat exchanger (2) in which the treated pyrolysis product is cooled to a temperature of from 25 to 100 °C. Optionally, a pressure control valve (15) can be used to regulate the pressure and keep the treated pyrolysis product being in liquid phase. In this example the pressure control valve (15) is located downstream of the heat exchanger (2). The subsequent washing and neutralisation steps as well as separation steps are identical to those as for the first embodiment of the intention as described above and shown in Figure 1. Insofar, reference is made to the respective description for the first embodiment of the intention above and Figure 1. A purified pyrolysis product is obtained and withdrawn via purified pyrolysis product outlet (11).

[0100] In Figure 3 an exemplary process falling under the third embodiment of the invention is schematically shown. In essence, the third embodiment of the invention can be seen a combination of the first embodiment and the second embodiment of the invention. The third embodiment enables the parallel purification of a crude pyrolysis product of which a first part is of the crude pyrolysis product is in gaseous phase and a second part is of the crude pyrolysis product is in liquid phase.

[0101] In this example shown in Figure 3, a liquid crude pyrolysis product having a final boiling point (FBP) of about 500 °C is provided and is fed via a crude pyrolysis product feed inlet (13) to a preheater (6). The preheater (6) heats the liquid crude pyrolysis product to a temperature of 350 °C. Those fractions of the liquid crude pyrolysis product having a final boiling point of up to 350 °C will accordingly be brought into the gas phase and form the first part of the crude pyrolysis product, whereas those fractions having a final boiling point of more than 350 °C will remain in the liquid phase and form the second part of the crude pyrolysis product. The first part of the crude pyrolysis product being in the gaseous phase is separated from the second part of the crude pyrolysis product being in the liquid phase in a vapour-liquid separator (16).

[0102] The first part of the crude pyrolysis product is subsequently treated with molten sodium hydroxide in a reactor (1) as described above for the first embodiment to obtain a first treated pyrolysis product, whereas the second part of the crude pyrolysis product is subsequently treated with solid sodium hydroxide in a heating apparatus (19) as described above for the second embodiment to obtain a second treated pyrolysis product. The second treated pyrolysis product is subsequently cooled in a cooler (20) and pressure control valve (15) is used to regulate the pressure so as to keep the treated pyrolysis product in liquid phase. In this example, the first treated pyrolysis product is combined with the second treated pyrolysis product to obtain a combined treated pyrolysis product. This combined treated pyrolysis product is further treated as described in the second embodiment of the invention as described above. A purified pyrolysis product is obtained and withdrawn via purified pyrolysis product outlet (11).

EXAMPLE SECTION

Materials

[0103] Commercially available batches of crude pyrolysis oils (Recycled Carbon Fuel) from Renasci Oostende Recycling NV were used in the following examples. The crude pyrolysis oil is characterized by a boiling point from 50 °C to 482.5 °C. Properties of the used different batches of the crude pyrolysis oils for the examples are given in Table 1 below.

Analytical methods

Chlorine content in pyrolysis oil

[0104] Instrument: 2019.010 (combustion) and 2019.080 (fraction collector) Xprep C-IC from TE Instruments with Archie injection and liquid boat, 19250020 ECO IC from Metrohm
Testing method: ASTM D7359 - 18 (Standard Test Method for Total Fluorine, Chlorine and Sulphur in Aromatic Hydrocarbons and Their Mixtures by Oxidative Pyrohydrolytic Combustion followed by Ion Chromatography Detection (Combustion Ion Chromatography-CIC))

[0105] Each pyrolysis oil sample was measured in triplicate.

Nitrogen content in pyrolysis oil

[0106]

Instrument: Xplorer-NS from TE Instruments with Archie injection and liquid boat

Testing methods:

ASTM D5762 - 18a (Standard Test Method for Nitrogen in Liquid Hydrocarbons, Petroleum and Petroleum Products by Boat-Inlet Chemiluminescence) ASTM D4629 - 17 (Standard Test Method for Trace Nitrogen in Liquid Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection)
ASTM D4629 was used for analyzing pyrolysis oil with a nitrogen concentration below 1000 ppm, whereas ASTM D5762 was used for analyzing pyrolysis oil with a nitrogen concentration above 1000 ppm.

[0107] Each sample was measured in triplicate.

Sulphur content in pyrolysis oil

[0108]

Instrument: Xplorer-NS from TE Instruments with Archie injection and liquid boat

Testing method: ASTM D5453 - 19a (Standard Test Method for Determination of Total Sulphur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence)

Each sample was measured in triplicate.

Final boiling point (FBP)

[0109] The final boiling point was determined according to ASTM D2887.

Examples

[0110] A setup according to the second embodiment of the invention and shown in Figure 2 was used. Liquid pyrolysis oil (40 ml, 31.6 g) was mixed with 0.29 g solid sodium hydroxide and subsequently heated to 350 °C using an autoclave reactor at a pressure of 8 to 9 bar. Accordingly, the weight ratio between the pyrolysis oil and the solid sodium hydroxide is 109 : 1. The residence time was varied between less than 0.5 min to 30 min, see Table 1 below. The obtained mixture was cooled to room temperature and washed with 10 ml water, and the aqueous phase was separated from the treated pyrolysis oil by centrifugation. Chlorine, nitrogen and sulphur impurities were measured as described above. "Reference" in Table 1 shows the properties of the crude pyrolysis oil before purification.

Table 1 Solid NaOH treatment at 350 °C

	Chlorine			**Nitrogen**			**Sulphur**		
Residence time	ppm	SD	% removed	ppm	SD	% removed	ppm	SD	% removed
Reference	13.17	0.06		942.51	2.46		16.07	0.23	
<0.5 min	2.75	0.09	79.12 %	298.84	0,32	68.29 %	10.79	0.16	32.86 %
10 min	1.42	0.04	89.22 %	303,56	0,08	67.79 %	10.59	0.04	34.10 %
30 min	1	0.07	92.41 %	308.74	0.56	67.24 %	10.41	0.11	35.22 %

[0111] As can be seen from Table 1, already after a residence time of less than 0.5 min a majority of the impurities has been removed.

[0112] Table 2 below shows the correlation of the residence time and final boiling point (FBP).

Table 2 Correlation of residence time and final boiling point (FBP)

NaOH [solid] treatment at 350 °C	**Pyrolysis oil**
Residence time	FBP **/ °C
Reference	416.8
<1 min *	426.1
10 min	437.6
30 min	457.9
1 hour	489.8
3 hours	535.4
*Reactor was heated to 350 °C and immediately cooled. **FBP is reported as average of two experiments.	

[0113] As can be seen from Table 2, it has been found that with increasing residence time the final boiling point of the pyrolysis product also increases. As an increase in the final boiling point is generally not desired, the residence time should be kept as shot as possible. With reference to Table 1, already after a residence time of less than 0.5 min a majority of the impurities has been removed and at the same time the final boiling point has not significantly increased.

Claims

1. Process for the purification of a crude pyrolysis product, the process comprising the steps of

   A1) providing a crude pyrolysis product, the crude pyrolysis product comprising hydrocarbons and impurities, the crude pyrolysis product at least partially originating from pyrolysis of plastic waste,
   A2) bringing the crude pyrolysis product into contact with alkali hydroxide at a temperature of from 330 to 400 °C, preferably 340 to 360 °C, in a continuous mode with a residence time of less than 10 min to obtain a treated pyrolysis product and a residue comprising reacted impurities,
   A3) washing the treated pyrolysis product with a polar washing solvent to obtain a purified pyrolysis product and a polar washing solvent phase,
   A4) separating the polar washing solvent phase from the purified pyrolysis product obtained in step A3).

2. Process according to claim 1, wherein the crude pyrolysis product is substantially in gaseous phase,
   wherein step A2) comprises bringing the crude pyrolysis product into contact with molten alkali hydroxide in a reactor (1) at a temperature of from 330 to 400 °C, preferably 340 to 360 °C, for a residence time of from 0.5 to less than 10 min in a continuous mode, and step A2) optionally further comprises cooling the treated pyrolysis product, preferably in a heat exchanger (2) and/or preferably to a temperature of from 25 to 100 °C.

3. Process according to claim 1, wherein the crude pyrolysis product is substantially in liquid phase,

   wherein step A2) comprises bringing the crude pyrolysis product into contact with solid alkali hydroxide in a mixing unit (18) and heating with a heating apparatus (19) to a temperature of from 330 to 400 °C, preferably 340 to 360 °C, preferably at a pressure in the heating apparatus (19) of from 0.5 to 50 bar in a continuous mode for a residence time of from 0.5 to less than 10 min, preferably the weight ratio between the crude pyrolysis product and the solid alkali hydroxide being from 10:1 to 1000:1, more preferably 50:1 to 500:1,
   and step A2) optionally further comprises cooling the treated pyrolysis product, preferably in a heat exchanger (2) and/or preferably to a temperature of from 25 to 100 °C.

4. Process according to claim 1, wherein a first part of the crude pyrolysis product is in gaseous phase and a second part of the crude pyrolysis product is in liquid phase,

   wherein step A2) comprises bringing the first part of the crude pyrolysis product into contact with molten alkali hydroxide in a reactor (1) at a temperature of from 330 to 400 °C, preferably 340 to 360 °C, for a residence time of from 0.5 to less than 10 min in a continuous mode to obtain a first treated pyrolysis product,
   wherein step A2) further comprises bringing the second part of the crude pyrolysis product into contact with solid alkali hydroxide in a mixing unit (18) and heating with a heating apparatus (19) to a temperature of from 330 to 400 °C, preferably 340 to 360 °C, in a continuous mode for a residence time of from 0.5 to less than 10 min, to obtain a second treated pyrolysis product, preferably the weight ratio between the second part of the crude pyrolysis product and the solid alkali hydroxide being from 10:1 to 1000:1, more preferably 50:1 to 500:1,
   and wherein step A2) optionally further comprises cooling the first treated pyrolysis product, preferably in a heat exchanger (2) and/or preferably to a temperature of from 25 to 100 °C, and/or
   optionally further comprises cooling the second treated pyrolysis product, preferably in a heat exchanger (2) and/or preferably to a temperature of from 25 to 100 °C,
   further comprising step A2a) of combining the optionally cooled first treated pyrolysis product and the optionally cooled second treated pyrolysis product to obtain a combined treated pyrolysis product, optionally cooling the combined treated pyrolysis product obtained in step A2a) to obtain a cooled combined treated pyrolysis product,
   wherein step A3) comprises washing the optionally cooled combined treated pyrolysis oil obtained in step A2a) with the polar washing solvent.

5. The process according to claim 2 or claim 4, wherein in step A2) the reactor (1) is a bubble column reactor.

6. The process according to any one of claims 2, 4 or 5, wherein in step A2) the reactor (1) further comprises heating

means for controlling the heat in the reactor (1), preferably the heating means comprising microwaves and/or electric heating.

7. The process according to claim 3 or claim 4, wherein in step A2) the mixing unit (18) is a homogenizing pump.

8. The process according to any one of claims 3, 4 or 7, wherein the heating apparatus (19) in step A2) is a heat exchanger, preferably the heat exchanger being a tube heat exchanger, preferably the heat exchanger being an electrically heated or a fired heat exchanger or an electrically heated or a fired tube heat exchanger.

9. The process according to any one of the preceding claims, wherein the alkali hydroxide of step A2) comprises, or consists of, sodium hydroxide, potassium hydroxide or mixtures thereof, preferably comprises, or consists of, sodium hydroxide.

10. The process according to any one of the preceding claims, wherein the polar washing solvent of step A3) comprises, or consists of, water, an alkanol or a mixture thereof, preferably comprises, or consists of, water.

11. The process according to any one of the preceding claims, wherein in step A3) the polar washing solvent further comprises an acid, preferably the acid comprises, or consists of, sulphuric acid, hydrochloric acid or phosphoric acid, more preferably the acid comprises, or consists of, sulphuric acid.

12. The process according to claims 1, 2, 4 to 11, wherein the crude pyrolysis product provided in step A1) is pre-heated to a temperature within the range of from 330 °C to 400 °C prior to step A2).

13. The process according to any one of the preceding claims, wherein step A3) is carried out in a mixing device (4), preferably the mixing device being a mixer or a static mixer.

14. The process according to any one of the preceding claims, wherein step A4) is carried in a separation device (5), the separation device preferably being a settler tank or a mixer-settler system, more preferably a mixer-settler system.

15. A method for producing a cracker feedstock comprising the step of blending 1 to 100 wt.% of a purified pyrolysis oil based on the total weight of the cracker feedstock and 0 to 99 wt.% of fossil naphtha based on the total weight of the cracker feedstock, wherein the purified pyrolysis oil is obtained by the process according to any one of claims 1 to 14.

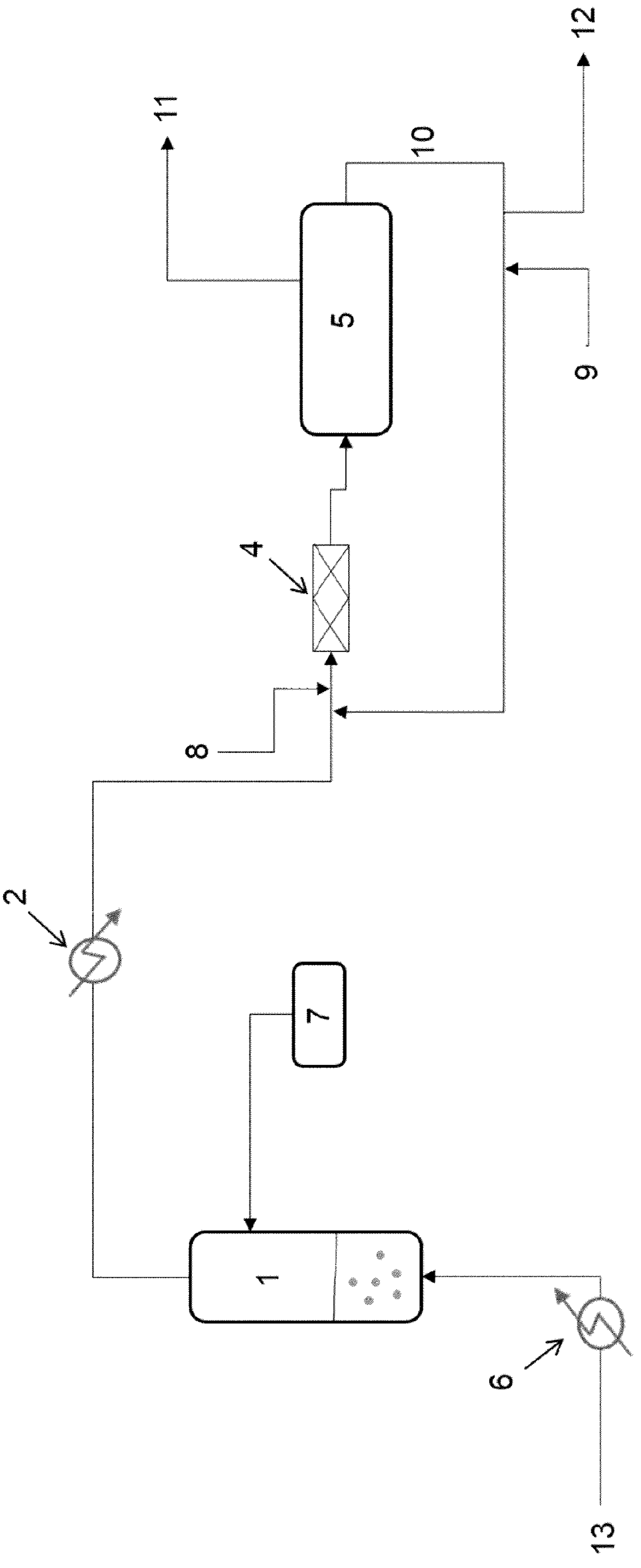

Figure 1

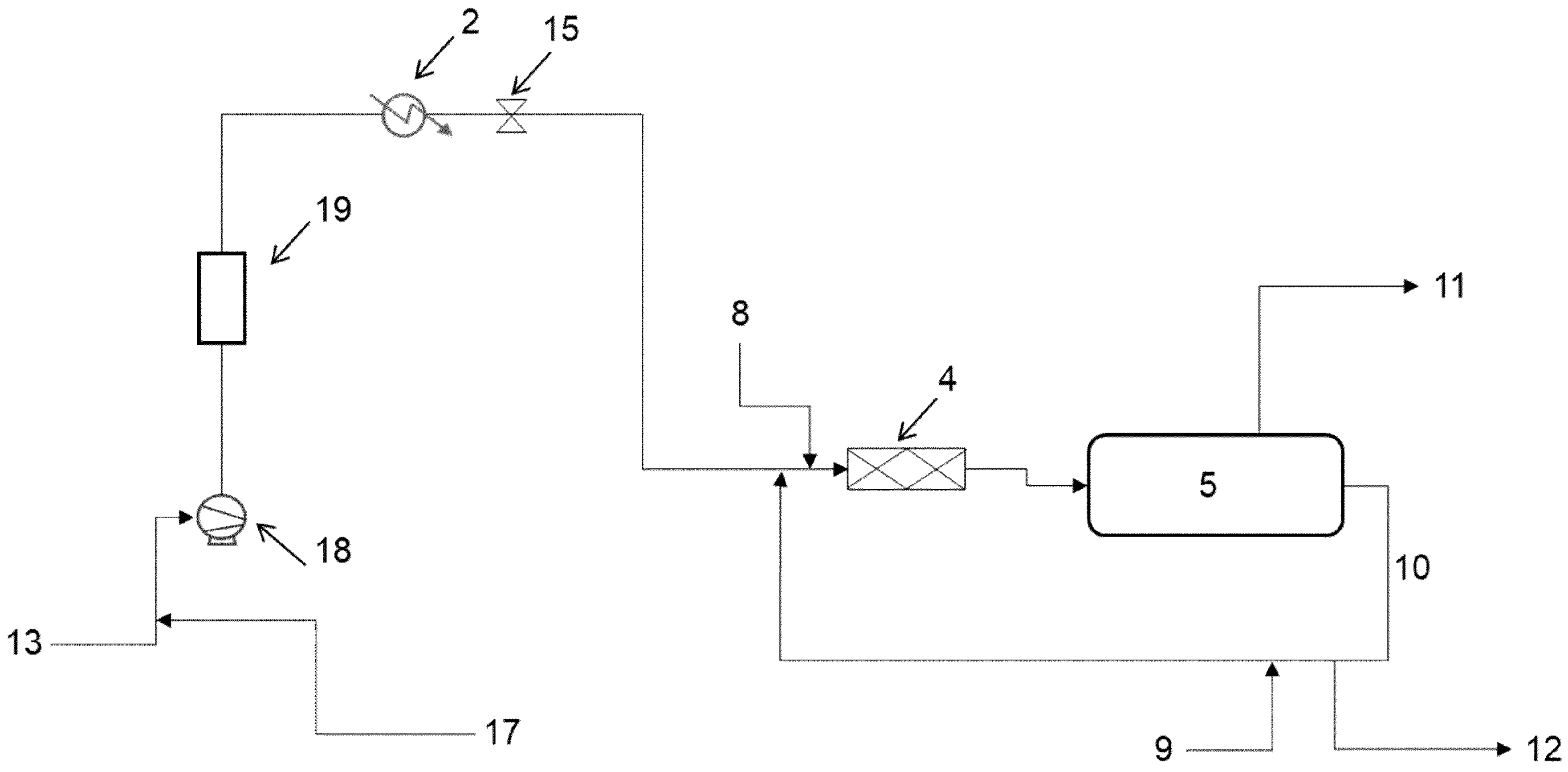

Figure 2

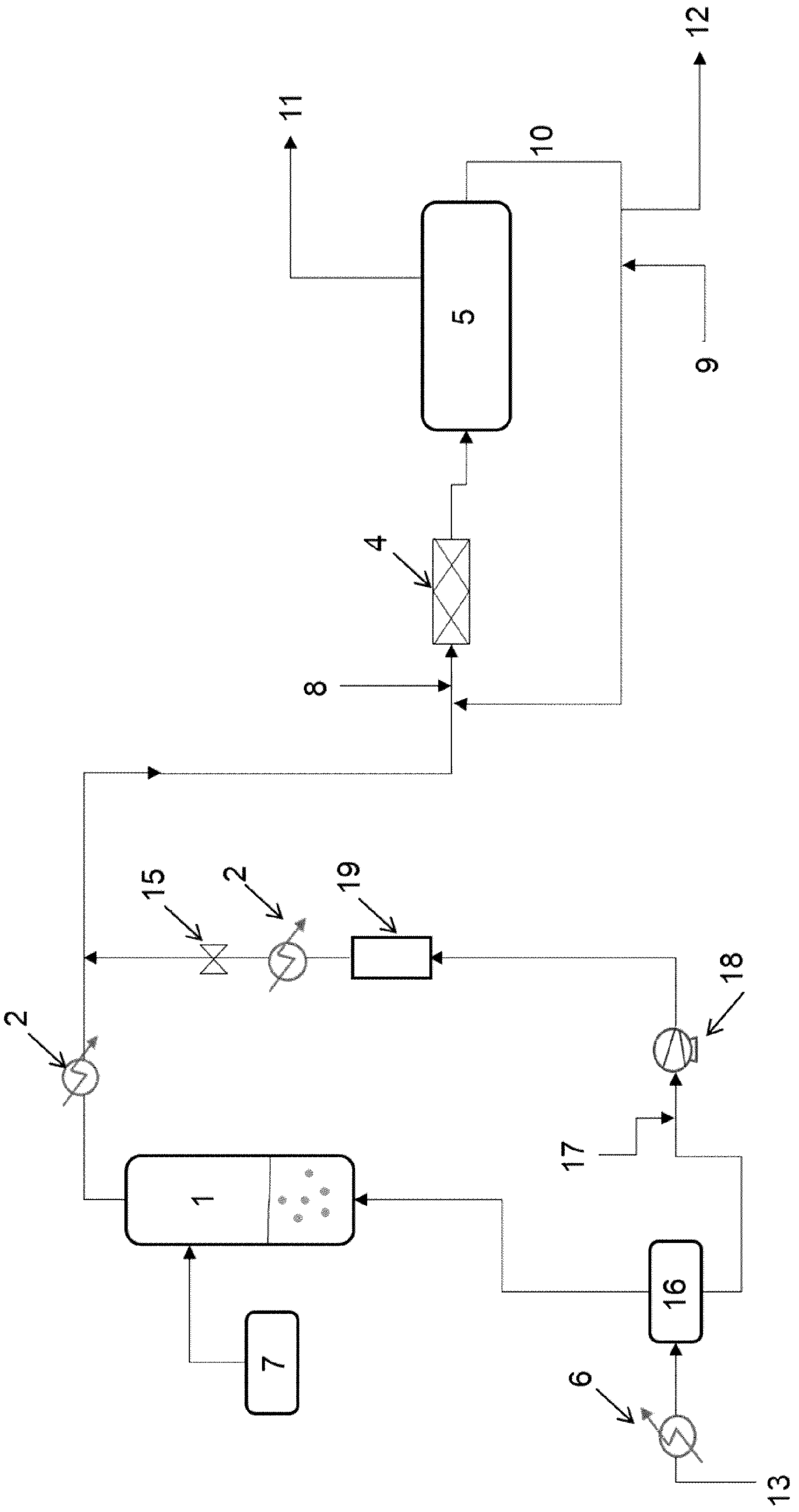

Figure 3

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Patentamt
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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	3 May 2024	Deurinck, Patricia

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X : particularly relevant if taken alone
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A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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