

**DELAYED COKING PROCESS FOR PRODUCING FREE-FLOWING
COKE USING LOW MOLECULAR WEIGHT AROMATIC ADDITIVES**

FIELD OF THE INVENTION

[0001] The present invention relates to a delayed coking process for making substantially free-flowing coke, preferably free flowing shot coke. A coker feedstock, such as a vacuum residuum, is heated in a heating zone to coking temperatures then conducted to a coking zone wherein volatiles are collected overhead and coke is formed. A suitable low molecular weight aromatic additive is added to the feedstock prior to it being heated in the heating zone, prior to its being conducted to the coking zone, or both, to enhance the formation of free flowing coke.

DESCRIPTION OF RELATED ART

[0002] Delayed coking involves the thermal decomposition of petroleum residua (resids) to produce gas, liquid streams of various boiling ranges, and coke. Delayed coking of resids from heavy and heavy sour (high sulfur) crude oils is carried out primarily as a means for disposing of these low value feedstocks by converting part of the resid to more valuable liquid and gaseous products. Although the resulting coke is generally thought of as a low value by-product, it may have some value, depending on its grade, as a fuel (fuel grade coke), for electrodes for aluminum manufacture (anode grade coke), etc.

[0003] In the delayed coking process, the feedstock is rapidly heated in a fired heater or tubular furnace. The heated feedstock is then passed to a coking drum that is maintained at conditions under which coking occurs, generally at temperatures above 400°C under super-atmospheric pressures. The heated

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residuum feed in the coker drum also forms volatile components that are removed overhead and passed to a fractionator, leaving coke behind. When the coker drum is full of coke, the heated feed is switched to another drum and hydrocarbon vapors are purged from the coke drum with steam. The drum is then quenched with water to lower the temperature to less than 300°F (149°C) after which the water is drained. When the cooling and draining steps are complete, the drum is opened and the coke is removed after drilling and/or cutting using high velocity water jets.

[0004] A hole is typically bored through the center of the coke bed using high pressure jets of water from nozzles located on a boring tool. Nozzles oriented horizontally on the head of a cutting tool then cut the coke from the drum. The coke removal step adds considerably to the throughput time and cost of the overall process. Thus, it would be desirable to be able to produce a free-flowing coke, in a coker drum, that would not require the expense and time associated with conventional coke removal.

[0005] Even though the coker drum may appear to be completely cooled, areas of the drum do not completely cool. This phenomenon, sometimes referred to as "hot drum", may be the result of a combination of morphologies of coke being present in the drum, which may contain a combination of more than one type of solid coke product, i.e., needle coke, sponge coke and shot coke. Since unagglomerated shot coke may cool faster than other coke morphologies, such as large shot coke masses or sponge coke, it would be desirable to produce predominantly substantially free flowing coke, preferably shot coke, in a delayed coker, in order to avoid or minimize hot drums.

SUMMARY OF THE INVENTION

[0006] In an embodiment, there is provided a delayed coking process comprising:

- (a) heating a petroleum resid in a first heating zone, to a temperature below coking temperatures but to a temperature wherein the resid is a pumpable liquid;
- (b) conducting said heated resid to a second heating zone wherein it is heated to coking temperatures;
- (c) conducting said heated resid from said second heating zone to a coking zone wherein vapor products are collected overhead and a solid coke product is formed;
- (d) introducing into said resid at least one low molecular weight aromatic additive that is effective for the formation of substantially free-flowing coke, wherein said additive is introduced into said resid at a point upstream of the second heating zone, between said second heating zone and said coking zone, or both.

[0007] In a preferred embodiment, the coking zone is in a delayed coker drum, and a substantially free-flowing shot coke product is formed.

[0008] In another embodiment, there is provided a delayed coking process comprising:

- (a) contacting a vacuum resid with an effective amount of at least one low molecular weight aromatic additive at a temperature from 70°C to

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370°C for a time sufficient to disperse the additive substantially uniformly into the feed;

- (b) heating the contacted vacuum resid to a temperature effective for coking said feed;
- (c) charging said heated treated resid to a coking zone at a pressure from 15 to 80 psig (103.42 to 551.58 kPa) for an effective amount of time to allow a bed of hot coke to form, at least a portion of which is free-flowing; and
- (d) quenching at least a portion of the bed of hot coke with water.

[0009] In another embodiment the low molecular weight additive is selected from one and two ring aromatic systems having from one to four alkyl substituents, which alkyl substituents contain one to eight carbon atoms, preferably from one to four carbon atoms, and more preferably from one to two carbon atoms. The one or more rings can be homonuclear or heteronuclear. By homonuclear aromatic rings is meant aromatic rings containing only carbon and hydrogen. By heteronuclear aromatic ring is meant aromatic rings that contain nitrogen, oxygen and sulfur in addition to carbon and hydrogen.

[0010] In another embodiment a substantially free-flowing shot coke product is formed and removed from the coking zone. The coking zone is preferably a delayed coker drum. The additive can be incorporated and combined with the feed either before the feed is introduced into the heating zone, which is a coker furnace, or it can be introduced into the feed between the coker furnace and coker drum. It is also within the scope of this invention that the additive be introduced into the

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feed in both locations. The same additive, or additives, can be added independently at each location or a different additive or additives can be added at each location.

[0011] Use of the term "combine" and "contact" are meant in their broad sense, i.e., that in some cases physical and/or chemical changes in the additive and/or the feed can occur. In other words, the invention is not restricted to cases where the additive and/or feed undergo no chemical and/or physical change following, or in the course of, the contacting and/or combining. An "effective amount" of additive is the amount of additive(s) that when contacted with the feed would result in the formation of free flowing coke in the coking zones, preferably substantially free-flowing shot coke. An effective amount will typically ranges from 10 to 5000 ppm (based on the total weight of the feed), and will depend on such things as the species of additive employed and its chemical and physical form. The effective amount will typically be less for additives species in a physical and chemical form that lead to better dispersion in the feed than for additive species that are more difficult to disperse. Thus, additives that are at least partially soluble in organics, more preferably in the resid feed, are most preferred.

[0012] Uniform dispersal of the additive into the resid feed is desirable to avoid heterogeneous areas of coke morphology formation. That is, one does not want locations in the coke drum where the coke is substantially free flowing and other areas where the coke is substantially non-free flowing. Dispersing of the additive is accomplished by any suitable technique, preferably by introducing a side stream of the additive into the feed at the desired location. The additive can be added by solubilization of the additive into the resid feed. Reducing the viscosity of the resid prior to mixing in the additive, e.g., by heating, solvent addition, etc. will facilitate solubilization of the additive into the resid feed. High energy mixing or use of

static mixing devices, may be employed to assist in dispersal of the additive, especially useful for additives that have relatively low solubility in the feedstream.

[0013] Preferably, all or substantially all of the coke formed in the process of the present invention is substantially free-flowing coke, more preferably, substantially free-flowing shot coke. It is also preferred that at least a portion of volatile species present in the coker drum during and after coke formation be separated and conducted away from the process, preferably overhead of the coker drum.

BRIEF DESCRIPTION OF THE FIGURES

[0014] Figure 1 hereof is a photomicrograph of coke residue as observed under cross polarized light microscopy for the PTE residue of Example 1 hereof.

[0015] Figure 2 hereof is a photomicrograph of coke residue as observed under cross polarized light microscopy for the PDI residue of Example 1 hereof.

[0016] Figure 3 hereof is a photomicrograph of coke residue as observed under cross polarized light microscopy obtained from treating the vacuum resid of Example 2 hereof with toluene as the additive.

[0017] Figure 4 hereof is a photomicrograph of coke residue as observed under cross polarized light microscopy obtained without treating the resid of Example 2 hereof with toluene.

[0018] All photomicrographs in these Figures used cross-polarized light optical microscopy, with a viewing area of 170 by 136 micrometers.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Petroleum vacuum residua ("resid") feedstocks are suitable for delayed coking. Such petroleum residua are frequently obtained after removal of distillates from crude feedstocks under vacuum and are characterized as being comprised of components of large molecular size and weight, generally containing: (a) asphaltenes and other high molecular weight aromatic structures that would inhibit the rate of hydrotreating/hydrocracking and cause catalyst deactivation; (b) metal contaminants occurring naturally in the crude or resulting from prior treatment of the crude, which contaminants would tend to deactivate hydrotreating/hydrocracking catalysts and interfere with catalyst regeneration; and (c) a relatively high content of sulfur and nitrogen compounds that give rise to objectionable quantities of SO₂, SO₃, and NO_x upon combustion of the petroleum residuum. Nitrogen compounds present in the resid also have a tendency to deactivate catalytic cracking catalysts.

[0020] In an embodiment, resid feedstocks include, but are not limited to, residues from the atmospheric and vacuum distillation of petroleum crudes or the atmospheric or vacuum distillation of heavy oils, visbroken resids, coal liquids, shale oil, tars from deasphalting units or combinations of these materials. Atmospheric and vacuum topped heavy bitumens can also be employed. Typically, such feedstocks are high-boiling hydrocarbonaceous materials having a nominal initial boiling point of 538°C or higher, an API gravity of 20° or less, and a Conradson Carbon Residue content of 0 to 40 weight percent.

[0021] Resid feeds are typically subjected to delayed coking. Generally, in delayed coking, a residue fraction, such as a petroleum residuum feedstock is pumped to a heater at a pressure of 50 to 550 psig (344.74 to 3792.12 kPa), where it

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is heated to a temperature from 480°C to 520°C. It is then discharged into a coking zone, typically a vertically-oriented, insulated coker drum through an inlet at the base of the drum. Pressure in the drum is usually relatively low, such as 15 to 80 psig (103.42 to 551.58 kPa) to allow volatiles to be removed overhead. Typical operating temperatures of the drum will be between 410°C and 475°C. The hot feedstock thermally cracks over a period of time (the "coking time") in the coker drum, liberating volatiles composed primarily of hydrocarbon products, that continuously rise through the coke mass (bed) and are collected overhead. The volatile products are sent to a coker fractionator for distillation and recovery of coker gases, naphtha, light gas oil, and heavy gas oil fractions. In an embodiment, a small portion of the heavy coker gas oil present in the product stream introduced into the coker fractionator can be captured for recycle and combined with the fresh feed (coker feed component), thereby forming the coker heater or coker furnace charge. In addition to the volatile products, delayed coking also forms solid coke product.

[0022] There are generally three different types of solid delayed coker products that have different values, appearances and properties, i.e., needle coke, sponge coke, and shot coke. Needle coke is the highest quality of the three varieties. Needle coke, upon further thermal treatment, has high electrical conductivity (and a low coefficient of thermal expansion) and is used in electric arc steel production. It is relatively low in sulfur and metals and is frequently produced from some of the higher quality coker feedstocks that include more aromatic feedstocks such as slurry and decant oils from catalytic crackers and thermal cracking tars. Typically, it is not formed by delayed coking of resid feeds.

[0023] Sponge coke, a lower quality coke, is most often formed in refineries. Low quality refinery coker feedstocks having significant amounts of asphaltenes,

heteroatoms and metals produce this lower quality coke. If the sulfur and metals content is low enough, sponge coke can be used for the manufacture of electrodes for the aluminum industry. If the sulfur and metals content is too high, then the coke can be used as fuel. The name "sponge coke" comes from its porous, sponge-like appearance. Conventional delayed coking processes, using the preferred vacuum resid feedstock of the present invention, will typically produce sponge coke, which is produced as an agglomerated mass that needs an extensive removal process including drilling and water-jet technology. As discussed, this considerably complicates the process by increasing the cycle time.

[0024] Shot coke is considered the lowest quality coke. The term "shot coke" comes from its shape that is similar to that of BB sized [1/16 inch to 3/8 inch (.16 to .95 centimeter)] balls. Shot coke, like the other types of coke, has a tendency to agglomerate, especially in admixture with sponge coke, into larger masses, sometimes larger than a foot in diameter. This can cause refinery equipment and processing problems. Shot coke is usually made from the lowest quality high resin-asphaltene feeds and makes a good high sulfur fuel source, particularly for use in cement kilns and steel manufacture. There is also another coke, which is referred to as "transition coke" and this refers to a coke having a morphology between that of sponge coke and shot coke or composed of a mixture of shot coke bonded to sponge coke. For example, coke that has a mostly sponge-like physical appearance, but with evidence of small shot spheres beginning to form as discrete shapes.

[0025] Substantially free-flowing shot coke can be produced in accordance with the present invention by treating the residuum feedstock with one or more low molecular weight aromatic additives. The additives are those that enhance the production of shot coke during delayed coking. The resid feed is subjected to

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treatment with one or more additives, at effective temperatures, i.e., at temperatures that will encourage the additives' dispersal in the feed stock . Such temperatures will typically be from 70°C to 500°C, preferably from 150°C to 370°C, more preferably from 185°C to 350°C.

[0026] The low molecular weight aromatic additives of the present invention are selected from one and two ring aromatic systems having from one to four alkyl substituents, which alkyl substituents contain one to eight carbon atoms, preferably from one to four carbon atoms, and more preferably from one to two carbon atoms. The one or more rings can be homonuclear or heteronuclear. By homonuclear aromatic rings is meant aromatic rings containing only carbon and hydrogen. By heteronuclear aromatic ring is meant aromatic rings that contain nitrogen, oxygen and sulfur in addition to carbon and hydrogen.

[0027] Non-limiting examples of low molecular weight aromatic additives include benzene, toluene, xylenes, methyl naphthalenes, dimethylnaphthates, indans, methyl indans, pyridine, methylpyridines, quinoline, and methylquinolines. The additive is use in an effective amount. That is, an amount that results in the desired amount of free-flowing coke. This amount will typically be from 10 wppm to 30,000 wppm, preferably from 10 wppm to 5000 wppm, and more preferably from 10 wppm to 50 wppm, based on the weight of the heavy oil feed.

[0028] It is within the scope of this invention that a second type of additive be used in combination with the polymeric additive. This second type of additive will be a metals-containing additive that can be used in liquid or solid form, with liquid form being preferred. Non-limiting examples of metals-containing additives that can be used in the practice of the present invention include metal hydroxides, naphthenates and/or carboxylates, metal acetylacetonates, Lewis acids, a metal

sulfide, metal acetate, metal carbonate, high surface area metal-containing solids, inorganic oxides and salts of oxides. Preferred metals of the hydroxides are the alkali and alkaline-earth metals, more preferably potassium and sodium. Salts that are basic are preferred

[0029] It is preferred that the fraction of 900°F to 1040°F (482.22°C to 560°C) atmospheric equivalent boiling point (AEBP) material be kept under 10 wt.%, which will push coke morphology back to a less bonded and less self-supporting coke morphology.

[0030] The precise conditions at which the resid feedstock is treated with the additive is feed and additive dependent. That is, the conditions at which the feed is treated with the additive are dependent on the composition and properties of the feed to be coked and the additive used. These conditions can be determined conventionally. For example, several runs can be made with a particular feed containing an additive at different times and temperatures by coking in a bench-scale reactor such as a Microcarbon Residue Test Unit (MCRTU). The resulting coke is then analyzed by use of optical cross-polarized light microscopy as set forth herein. The preferred coke morphology (i.e., one that will produce substantially free-flowing coke) is a coke microstructure of discrete micro-domains having an average size of 0.5 to 10 μm , preferably from 1 to 5 μm , somewhat like the mosaic shown in Figures 2, 3 and 5 hereof. Coke microstructure that represents coke that is not free-flowing shot coke is shown in Figure 1 hereof, showing a coke microstructure that is composed substantially of non-discrete, or substantially large flow domains up to 60 μm or greater in size, typically from 10 to 60 μm .

[0031] Conventional coke processing aids, including an antifoaming agent, can be employed in the process of the present invention. While shot coke has been

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produced by conventional methods, it is typically agglomerated to such a degree that water-jet technology is still needed for its removal.

[0032] In one embodiment of the present invention, the resid feedstock is first treated with the low molecular weight additive of the present invention that encourages the formation of substantially free-flowing coke. By keeping the coker drum at relatively low pressures, much of the evolving volatiles can be collected overhead, which prevents undesirable agglomeration of the resulting shot coke. The combined feed ratio ("CFR") is the volumetric ratio of furnace charge (fresh feed plus recycle oil) to fresh feed to the continuous delayed coker operation. Delayed coking operations typically employ recycles of 5 vol.% to 25% (CFRs of 1.05 to 1.25). In some instances there is 0 recycle and sometimes in special applications recycle up to 200%. CFRs should be low to aid in free flowing shot coke formation, and preferably no recycle should be used.

[0033] Typically, additive(s) are conducted to the coking process in a continuous mode. If needed, the additive can be dissolved or slurried into an appropriate transfer fluid, which will typically be solvent that is compatible with the resid and in which the additive is substantially soluble. The fluid mixture or slurry is then pumped into the coking process at a rate to achieve the desired concentration of additives in the feed. The introduction point of the additive can be, for example, at the discharge of the furnace feed charge pumps, or into the coker transfer line. There can be a pair of mixing vessels operated in a fashion such that there is continuous introduction of the additives into the coking process.

[0034] The rate of additive introduction can be adjusted according to the nature of the resid feed to the coker. Feeds that are on the threshold of producing shot

coke may require less additive than those which are farther away from the threshold.

[0035] For additives that are difficult to dissolve or disperse in resid feeds, the additive(s) are transferred into the mixing/slurry vessel and mixed with a slurry medium that is compatible with the feed. Non-limiting examples of suitable slurry mediums include coker heavy gas oil, water, etc. Energy may be provided into the vessel, e.g., through a mixer for dispersing the additive.

[0036] For additives that can be more readily dissolved or dispersed in resid feeds, the additive(s) are transferred into the mixing vessel and mixed with a fluid transfer medium that is compatible with the feed. Non-limiting examples of suitable fluid transfer mediums include warm resid (temp. between 150°C to 300°C), coker heavy gas oil, light cycle oil, heavy reformat, and mixtures thereof. Cat slurry oil (CSO) may also be used also, though under some conditions it may inhibit the additives' ability to produce loose shot coke. Energy may provided into the vessel, e.g., through a mixer, for dispersing the additive into the fluid transfer medium.

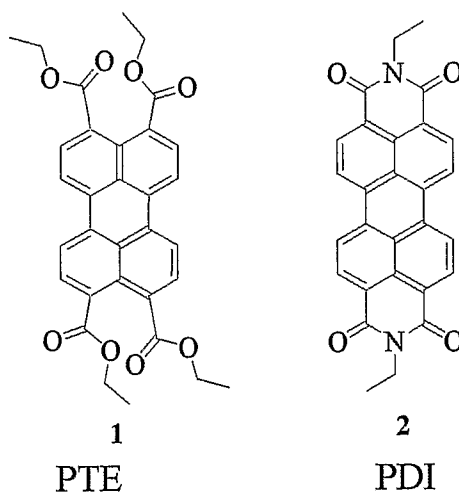
[0037] The present invention will be better understood by reference to the following non-limiting examples that are presented for illustrative purposes.

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EXAMPLES

EXAMPLE 1

[0038] In a first set of experiments two model polynuclear aromatic (PNA) compounds 1 (PET) and 2 (PDI) that are known and reported to form mesophases at temperatures in the range of 100°C to 450 °C were used to demonstrate that a PNA mesophase intermediate is involved in the formation of anisotropic mesophase coke. The model perylene PNA compounds are shown below.



[0039] The crystalline compound PTE, exhibits a liquid crystalline or mesophase between 140°C to 315°C. PTE was heated to 400 °C for 2 hours in a Microcarbon Residue (MCR) unit. Coke residue (60.4 %) was obtained. A photomicrograph of the coke residue as observed under a cross polarized light microscopy for PTE residue is shown in Figure 1 hereof. We observed an anisotropic coke morphology of medium sized domains (10-25 µm) with isolated regions of mesophase spheres (1-6 µm) indicating that a PNA mesophase intermediate is involved in the formation of anisotropic coke.

[0040] The crystalline compound PDI exhibits a liquid crystalline mesophase between 330°C to 480 °C. PDI was heated to 400 °C for 2 hours in a MCR unit. Coke residue (98.2 %) was obtained. A photomicrograph of the coke residue as observed under a polarized microscope for PDI is also shown in Figure 2 hereof. We observed anisotropic coke morphology with thin anisotropic laths (0.5-1 μm thick) indicating that a PNA mesophase intermediate is involved in the formation of anisotropic mesophase coke.

EXAMPLE 2

[0041] In this set of experiments; untreated sweet vacuum resid, Sweet VTB, and toluene additized SweetVTB (460 ppm) were used. Additized Sweet VTB was prepared by adding 20 mL of toluene to 10 g of resid and then evaporating the toluene at 100 °C for 24 hours. GC analysis of the residue showed a 460 wppm of residual toluene "bound" or "occluded" in the resid. This toluene-occluded resid was heated to 400 °C for 2 hours in an MCR unit. Coke residue (24.4%) was obtained. A photomicrograph of the coke residue as observed under a polarized microscope obtained from this experiment is shown in Figure 3 hereof. Photomicrograph of the coke residue as observed under a polarized microscope for the control run with no toluene additization is shown in Figure 4 hereof. Comparing Figures 3 and 4, we observe a much enhanced anisotropic coke morphology indicating that the occluded toluene enhances the formation of anisotropic coke. Based on our first set of experiments on the model compounds and the second set of experiments on Sweet VTB we infer that toluene alters the mesophase intermediate which results in the more rapid formation of anisotropic mesophase coke.

CLAIMS:

1. A delayed coking process comprising:
 - (a) heating a petroleum resid in a first heating zone, to a temperature below coking temperatures but to a temperature wherein the resid is a pumpable liquid;
 - (b) conducting said heated resid to a second heating zone wherein it is heated to coking temperatures;
 - (c) conducting said heated resid from said second heating zone to a coking zone wherein vapor products are collected overhead and a coke product is formed; and
 - (d) introducing into said resid at least one low molecular weight aromatic additive that is effective for the formation of substantially free-flowing coke, wherein said additive is introduced into said resid at a point upstream of the second heating zone, upstream of said coking zone, or both and wherein said additive is comprised of one or two homonuclear or heteronuclear aromatic rings having from one to four alkyl substituents, which alkyl substituents contain from one to eight carbon atoms.
2. A delayed coking process comprising:
 - (a) contacting a vacuum resid with an effective amount of at least one low molecular weight aromatic additive at a temperature from 70°C to 370°C for a time sufficient to disperse the agent uniformly into the feed, which additive is comprised of one or two aromatic rings having

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from one to four alkyl substituents, which alkyl substituents contain one to eight carbon atoms.

(b) heating the treated resid to a temperature effective for coking said feed;

(c) charging said heated treated resid to a coking zone at a pressure from 15 to 80 psig (103.42 to 551.58 kPa) for a coking time to form a bed of hot coke; and

(d) quenching at least a portion of the bed of hot coke with water.

3. The process of any preceding claim wherein the alkyl substituents contain one to four carbon atoms.
4. The process of any preceding claim wherein the residuum feedstock is vacuum resid.
5. The process of any preceding claim wherein the additive is selected one or more of toluene, benzene, xylenes, methyl naphthalenes, indans, methyl indans, pyridine, methylpyridines, quinoline, and methylquinolines.
6. The process of any preceding claim wherein the coke produced is substantially a shot coke.
7. The process of any preceding claim wherein said additive is introduced into said vacuum resid at a point upstream of the first heating zone, upstream of the second heating zone, or both.
8. The process of any preceding claim wherein an effective amount of a second additive is also used, which second additive is a metals-containing additive selected from metal naphthenate, metal acetylacetonate, a Lewis

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acid, a high surface area metal-containing material, an inorganic oxide, and salts of inorganic oxides.

9. The process of any preceding claim wherein the second additive is a metals-containing additive is one or more Lewis acid selected from of aluminum chloride, zinc chloride, iron chloride, titanium tetrachloride and boron trifluoride.
10. The process of any preceding claim wherein the second additive is one or more of KOH and NaOH.