

methods and the unfavorable reactions of consumers and governments to increased prices. The costs associated with fossil fuels are some of the major factors affecting the world economy.

SUMMARY

[0005] According to first broad example, the present disclosure provides a system for desulfurizing liquid fossil fuel comprising: liquid fossil fuel supply; a first mixer; a second mixer; an oxidizer supply; a catalyst supply; an extractant supply; a centrifuge; and an ultrasonically induced cavitation reactor comprising: a vessel configured to receiving the liquid fossil fuel, oxidizer and catalyst as a multiphase reaction medium; and a vibrating probe disposed within walls of the vessel. The multiphase reaction medium is configured to flow generally parallel to the probe. The probe is configured to produce pressure waves to induce formation of nano-sized bubbles in the multiphase reaction medium along one or more cavitation zones along a length of the probe. The vessel walls are at a distance of approximately 0.5 to 5 times the diameter of a smallest diameter of the probe. The first mixer is configured to receive and mix the liquid fossil fuel supply with the catalyst supply. The reactor is configured to receive the mix of liquid fossil fuel supply and the catalyst supply from the first mixer and the oxidizer supply. The second mixer is configured to receive the multiphase reaction medium and extractant supply to form processed fuel. The centrifuge is configured to receive the processed fuel from the second mixer to extract sulfones to yield an organic phase and aqueous phase. The organic phase substantially consists of desulfurized fuel.

[0005a] In one aspect, the present disclosure refers to a system for desulfurizing liquid fossil fuel comprising: liquid fossil fuel supply; a first mixer; a second mixer; an oxidizer supply; a catalyst supply; an extractant supply; a centrifuge; and an ultrasonically induced cavitation reactor comprising: a vessel configured to receiving the liquid fossil fuel, oxidizer and catalyst as a multiphase reaction medium; and a vibrating probe disposed within walls of the vessel, wherein the multiphase reaction medium is configured to flow generally parallel to the probe, wherein the probe is configured to produce pressure waves to induce formation of nano-sized bubbles in the multiphase reaction medium along one or more cavitation zones along a length of the probe, wherein the vessel walls are at a distance of approximately 0.5 to 5 times the diameter of a smallest diameter of the probe, wherein the first mixer is configured to receive and mix the liquid fossil fuel supply with the catalyst supply, wherein the reactor is configured to receive the mix of liquid fossil fuel supply and the catalyst supply from the first mixer and the oxidizer supply, wherein the second mixer is configured to receive the multiphase reaction medium and extractant supply to form processed fuel, wherein the centrifuge is configured to receive the processed fuel from the second mixer to extract sulfones to yield an organic phase and aqueous phase, wherein the organic phase substantially consists of desulfurized fuel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary embodiments of the invention, and, together with the general description given above and the detailed description given below, serve to explain the features of the invention.

[0007] FIG. 1 is an illustration of an exemplary ultrasonically induced cavitation (UIC) reactor according to one embodiment of the present disclosure.

[0008] FIG. 2 illustrates exemplary reaction zones during the formation of bubble clouds according to one embodiment of the present disclosure.

[0009] FIG. 3 illustrates an exemplary fluid flow within a disclosed reactor according to one embodiment of the present disclosure.

WHAT IS CLAIMED IS:

1. A system for desulfurizing liquid fossil fuel comprising:
 - liquid fossil fuel supply;
 - a first mixer;
 - a second mixer;
 - an oxidizer supply;
 - a catalyst supply;
 - an extractant supply;
 - a centrifuge; and
 - an ultrasonically induced cavitation reactor comprising:
 - a vessel configured to receiving the liquid fossil fuel, oxidizer and catalyst as a multiphase reaction medium; and
 - a vibrating probe disposed within walls of the vessel,
 - wherein the multiphase reaction medium is configured to flow generally parallel to the probe,
 - wherein the probe is configured to produce pressure waves to induce formation of nano-sized bubbles in the multiphase reaction medium along one or more cavitation zones along a length of the probe,
 - wherein the vessel walls are at a distance of approximately 0.5 to 5 times the diameter of a smallest diameter of the probe,
 - wherein the first mixer is configured to receive and mix the liquid fossil fuel supply with the catalyst supply,
 - wherein the reactor is configured to receive the mix of liquid fossil fuel supply and the catalyst supply from the first mixer and the oxidizer supply,
 - wherein the second mixer is configured to receive the multiphase reaction medium and extractant supply to form processed fuel,
 - wherein the centrifuge is configured to receive the processed fuel from the second mixer to extract sulfones to yield an organic phase and aqueous phase,
 - wherein the organic phase substantially consists of desulfurized fuel.

2. The system of claim 1 wherein ultra sound is applied to the multiphase reaction medium by the reactor to cause oxidation of sulfides in the liquid fossil fuel to sulfones.
3. The system of claim 1, wherein oxidation of sulfur components in the liquid fossil fuel occurs by separation of oxidized molecules using liquid-liquid extraction.
4. The system of claim 1, wherein the liquid fossil fuel is selected from a group of fuel comprising: VRO, HFO, Shale Oil and any other liquid fuel with high sulfur content (S wt% > 0.2) and high boiling point (>480 K).
5. The system of claim 1, wherein a ratio of the distance of the vessel walls to the smallest diameter of the probe is determined depending based on the flowrate and liquid fossil fuel.
6. The system of claim 5, wherein the probe comprises a sonotrode.
7. The system of claim 6, wherein a diameter of the sonotrode varies along its length.
8. The system of claim 6, wherein a geometrical configuration of the sonotrode produces the one or more cavitation zones along a length of the sonotrode.
9. The system of claim 6, wherein the sonotrode controls the temperature and pressure of the reactor.
10. The system of claim 9, wherein the temperature and pressure of the reactor is controlled by using the power output of the sonotrode as a feedback.
11. The system of claim 10, wherein a viscosity of the multiphase reaction medium affects the power of the sonotrode.
12. The system of claim 10, wherein the power output is adjusted based on a flowrate of the multiphase reaction medium.
13. The system of claim 1, wherein the reactor is configured to adjust a flowrate of the multiphase reaction medium based on achieving a prescribed residence time.
14. The system of claim 13, wherein the residence time in the reactor does not exceed 2 minutes per pass.

15. The system of claim 14, wherein up to 10 passes are applied.
16. The system of claim 1, wherein a ratio of $D_{\text{sonotrode}}/D_{\text{reactor}}$ is above 0.1 and below 1, where $D_{\text{sonotrode}}$ is a widest diameter of the probe along its longitudinal axis and D_{reactor} is a diametric distance between interior walls of the vessel along its longitudinal axis.
17. The system of claim 1, comprising:
vibrating the probe at a frequency ranging from approximately 2e5 Hz to 2.2e5 Hz.
18. The system of claim 17, wherein an amplitude of the frequency ranges from approximately 50-210 microns.
19. The system of claim 1, wherein the nano-sized bubbles are produced as micro bubbles having a micron diameter range.
20. The system of claim 1, wherein the reactor is configured to continually process the multiphase reaction medium.