

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 an ultrasonically induced cavitation reactor comprising: a vessel having an inlet for receiving a processing liquid and an outlet for exiting the processing liquid; and a vibrating probe disposed within walls of the vessel. The processing liquid 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 processing liquid 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.

**[0005a]** In one aspect, the present disclosure refers to an ultrasonically induced cavitation reactor comprising: a vessel having an inlet for receiving a processing liquid and an outlet for exiting the processing liquid; and a vibrating probe disposed within walls of the vessel, wherein the processing liquid 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 processing liquid 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 a diameter of a smallest diameter of the probe.

## **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.

**[0010]** FIG. 4 illustrates a process scheme according to one embodiment of the present disclosure.

**[0011]** FIG. 5 illustrates the occurrence of cavitation reproduced through computational fluid dynamics (CFD) simulations according to one embodiment of the present disclosure.

**[0012]** FIG. 6 illustrates the distribution of sulfur molecules in Arabian Extra Light (AXL) before and after sonication according to one embodiment of the present disclosure.

## WHAT IS CLAIMED IS:

1. An ultrasonically induced cavitation reactor comprising:  
a vessel having an inlet for receiving a processing liquid and an outlet for exiting the processing liquid; and  
a vibrating probe disposed within walls of the vessel,  
wherein the processing liquid 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 processing liquid 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 a diameter of a smallest diameter of the probe.
2. The reactor of claim 1, wherein a ratio of the distance of the vessel walls to the smallest diameter of the probe is determined based on a flowrate and processing liquid.
3. The reactor of claim 1, wherein the probe comprises a sonotrode.
4. The reactor of claim 3, wherein a diameter of the sonotrode varies along its length.
5. The reactor of claim 3, wherein the sonotrode has a self-synchronizing mechanism which controls a temperature and pressure of the reactor.
6. The reactor of claim 5, wherein the self-synchronizing mechanism is controlled by using a power output of the sonotrode as feedback.
7. The reactor of claim 6, wherein a viscosity of the processing liquid or a temperature in the reactor affects the power of the sonotrode.
8. The reactor of claim 7, wherein the power output is adjusted based on a flowrate of the processing liquid.
9. The reactor of claim 3, wherein the reactor is configured to adjust a flowrate of the processing liquid based on achieving a prescribed residence time.

10. The reactor of claim 9, wherein the residence time in the reactor does not exceed 2 minutes per pass.
11. The reactor of claim 1, wherein the probe is configured to vibrate at a frequency ranging from approximately  $2 \times 10^5$  Hz to  $2.2 \times 10^5$  Hz.
12. The reactor of claim 11, wherein an amplitude of the frequency ranges from approximately 50-210 microns.
13. The reactor 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  $D_{\text{reactor}}$  is a diametric distance between interior walls of the vessel along its longitudinal axis.
14. The reactor of claim 1, wherein the nano-sized bubbles are micro bubbles having a micron diameter range.
15. The reactor of claim 1, wherein the reactor is configured to radially inject an oxidizer and/or a catalyst intermittently or continuously.
16. The reactor of claim 15, wherein the oxidizer is hydrogen peroxide ( $\text{H}_2\text{O}_2$ ).
17. The reactor of claim 15, wherein the catalyst is an acidic medium.
18. The reactor of claim 17, wherein the acidic medium is acetic acid.
19. The reactor of claim 1, wherein the cavitation zones produced by the probe form an area larger than a main body of the probe.
20. The reactor of claim 1, wherein the processing liquid is selected from a group of fuel comprising: VRO, HFO, Shale Oil and any other liquid fuel with high sulfur content ( $\text{S wt\%} > 0.2$ ) and high boiling point ( $>480$  K).