CLAIMS

1. A computer implemented method to evaluate the performance of a multiphase separator system for separating a multi-liquid and multi-phase immiscible liquid dispersion comprising the steps of:

providing operational input parameters at a hardware processor of a controller computing device, wherein the processor is configured by executing program code that is in the form of one or more software modules and stored in a non-transitory storage medium, and wherein the operational input parameters include:

fluid property data for the immiscible liquid dispersion including one or more of density, viscosity and surface tension, static and dynamic settling data for the immiscible liquid dispersion, and

geometry of an internal volume of the separator including one or more internal geometric components therein;

generating, with the processor, a computational fluid dynamics (CFD) model of the separator system, wherein generating the CFD model includes:

defining, with the processor based on the geometry, a three-dimensional geometric model of the internal volume of the separator and the internal components therein,

defining, with the processor based on the three-dimensional model, a computational mesh representing the internal volume of the separator,

determining, with the processor, an initial droplet size distribution of the immiscible liquid dispersion contained within the internal volume,

representing volumes for each of a continuous or dispersed gas phase, a continuous or dispersed heavier liquid phase and a continuous or dispersed lighter liquid phase within the interior volume of the separator using a Eulerian multiphase model,

representing, for a volume of a dispersed liquid phase within the interior volume, a droplet size distribution using population balance modeling, wherein the distribution is modeled by solving a population balance equation according to multivariate methods,

applying, with the processor, coalescence and breakage kernels to model droplet size evolution in the population of the dispersed liquid phase as a function of

droplet size and the fluid property data including the static and dynamic settling data for the immiscible liquid dispersion, and

modeling a phase interaction between the dispersed liquid phase and the continuous liquid phase, wherein the model of the phase interaction is a function of a dispersed phase fraction concentration between a dilute regime, a semi-dilute regime and a concentrated regime of the dispersed liquid phase volume and is a function of the evolution of the dispersed liquid phase droplet size and a dispersion viscosity; and

outputting, with the processor based on the CFD model, one or more of the operational input parameters, wherein the output one or more operational parameters are adjusted based on the CFD model to maximize a separation efficiency of the separator.

2. The process of claim 1, wherein the immiscible liquid dispersion comprises an emulsion selected from the group consisting of: an oil in water emulsion; a water in oil emulsion; water-in-oil-in-water emulsion; and oil-in-water-in-oil emulsion.

3. The process of claim 1, wherein the processed liquid streams output from the separator include a water liquid stream and an oil liquid stream.

4. The process of claim 1, wherein providing static or dynamic settling data includes monitoring the liquid dispersion to determine a time-varying vertical distribution of a settling or rising phase in the separator.

5. The process of claim 4, wherein the time varying vertical distribution is determined by the processor using a sensor device configured to take one or more of: ultrasonic measurements, gamma densitometry measurements, nuclear magnetic resonance NMR measurements, and electrical tomography measurements of the liquid dispersion.

6. The process of claim 5, wherein the time-varying vertical distribution is measured in real-time from a batch processed by the separator or is measured during one or more previous batches.

7. The process of claim 4, further comprising: selecting, with the processor, the coalescence and breakage kernels based on the static or dynamic settling data.

8. The process of claim 1, wherein the fluid property data comprises values or gradients of values for one or more variables including: density, viscosity, surface tension, momentum, velocity, turbulence energy dissipation rate, turbulent kinetic energy, and demulsifier or surfactant concentration.

9. The process of claim 8, wherein droplet size evolution is modeled as a function of droplet size and one or more of the fluid property data variables.

10. A method for optimizing liquid-liquid separation efficiency in a multiphase separator system comprising the steps of:

providing a multiphase separator having an inlet for receiving a multi-liquid and multi-phase immiscible liquid dispersion comprising a gas phase, an oil phase, and a water phase;

passing the immiscible liquid dispersion into the separator;

electronically providing operational input parameters from a connected electronic device to a hardware processor of a controller computing device, wherein the processor is configured by executing code that is in the form of one or more software modules and stored in a non-transitory storage medium, and wherein the operational input parameters include:

fluid property data for the immiscible liquid dispersion including one or more of density, viscosity and surface tension, static and dynamic settling data for the immiscible liquid dispersion, and

geometry of an internal volume of the separator including one or more internal geometric components therein;

generating, with the processor, a computational fluid dynamics (CFD) model of the separator system, wherein generating the CFD model includes:

defining, with the processor executing code comprising a CFD model generator module, based on the geometry, a three-dimensional geometric model of the internal volume of the separator and the internal components therein,

defining, with the processor executing code comprising the CFD model generator module, based on the three-dimensional model, a computational mesh representing the internal volume of the separator,

determining, with the processor with the processor executing code comprising an input parameters module and the CFD model generator module, an initial droplet

size distribution of the immiscible liquid dispersion contained within the internal volume,

representing, with the processor with the processor executing code comprising the input parameters module and the CFD model generator module, volumes for each of a continuous or dispersed gas phase, a continuous or dispersed heavier liquid phase and a continuous or dispersed lighter liquid phase within the interior volume of the separator using a Eulerian multiphase model and as a function of multiple velocity classes,

representing, with the processor executing code comprising the input parameters module and the CFD model generator module, for a volume of a dispersed liquid phase within the interior volume, a droplet size distribution using population balance modeling, wherein the distribution is modeled by solving a population balance equation according to multivariate methods,

applying, with the processor with the processor executing code comprising the input parameters module and the CFD model generator module, coalescence and breakage kernels to model droplet size evolution in the population of the dispersed liquid phase as a function of droplet size and the fluid property data including the static and dynamic settling data for the immiscible liquid dispersion, and

modeling, with the processor executing code comprising a simulation module and the CFD model generator module, the phase interaction between the continuous liquid phase and the dispersed liquid phase, wherein the model of the phase interaction is a function of a dispersed phase fraction concentration between a dilute regime, a semi-dilute regime and a concentrated regime of the dispersed liquid phase volume and is a function of the evolution of the dispersed phase droplet size and a dispersion viscosity; and

adjusting, with the processor executing code comprising an adjustment module and the CFD model generator module, based on the CFD model, one or more of the operational input parameters to maximize the liquid-liquid separation efficiency; and

outputting from the separator one or more streams of processed liquids separated from the immiscible liquid dispersion and containing minimal amounts of the immiscible liquid dispersion.

11. The process of claim 10, wherein the immiscible liquid dispersion comprises an emulsion selected from the group consisting of: an oil in water emulsion; a water in oil emulsion; water-in-oil-in-water emulsion; and oil-in-water-in-oil emulsion.

12. The process of claim 10, wherein the processed liquid streams output from the separator include a water liquid stream and an oil liquid stream, and wherein the input parameters are adjusted to minimize the output of water-in-oil emulsion and oil-in-water emulsion in the processed liquid streams.

13. The process of claim 10, wherein providing static or dynamic settling data includes monitoring the immiscible liquid dispersion to determine a time-varying vertical distribution of a settling or rising phase in the separator.

14. The process of claim 13, wherein the time varying vertical distribution is determined by the processor using a sensor device configured to take one or more of: ultrasonic measurements, gamma densitometry measurements, nuclear magnetic resonance NMR measurements, and electrical tomography measurements of the liquid dispersion.

15. The process of claim 14, wherein the time-varying vertical distribution is measured in real-time from a batch processed by the separator or is measured during one or more previous batches.

16. The process of claim 13, further comprising: selecting, with the processor, the coalescence and breakage kernels based on the static or dynamic settling data.

17. The process of claim 1, wherein the fluid property data comprises values or gradients of values for one or more variables including: density, viscosity, surface tension, momentum, velocity, turbulence energy dissipation rate, turbulent kinetic energy, and demulsifier or surfactant concentration.

18. The process of claim 17, wherein droplet size evolution is modeled as a function of droplet size and one or more of the fluid property data variables.

19. The process of claim 10, wherein the initial droplet size distribution is determined from experimental measurements and includes the initial droplet diameter distribution and phase fractions for each probability distribution function defined by the probability distribution of droplets in terms of the volume fraction divided by the droplet diameter.

20. The process of claim 10, wherein the internal geometric components include one or more of: inlet devices, perforated plates, baffles, vortex breakers, weirs, coalescer packs, and devices obstructing or partially obstructing the flow of gas and liquid within the internal volume of the separator.