Claims

1. A system for separation of neutrally buoyant particles from a fluid, the system comprising:

an inlet to receive at least a portion of the fluid containing the neutrally buoyant particles;

a spiral channel within which the fluid flows in a manner such that the neutrally buoyant particles flow in a tubular band offset from a center of the channel;

a first outlet for the fluid within which the tubular band flows; and,

a second outlet for the remaining fluid;

wherein the inlet is angled to facilitate earlier formation of the tubular band along an inner wall of the spiral channel.

2. The system as set forth in claim 1 further comprising a second spiral channel nested with the spiral channel such that the tubular band is narrowed as a result of flowing through the second spiral channel.

3. The system as set forth in claim 1 wherein the remaining neutrally buoyant particles are of a different size than the neutrally buoyant particles output through the first outlet.

4. The system as set forth in claim 1 further comprising a second spiral channel within which at least another portion of the fluid flows.

5. The system as set forth in claim 1 further comprising a recirculation channel between the first outlet and the inlet.

6. The system as set forth in claim 1 wherein the tubular band is formed as a function of at least one of fluid viscosity, average channel velocity, particle radius, fluid density, hydraulic diameter of channel, angular velocity, and differential velocity across particles.

7. The system as set forth in claim 1 wherein the tubular band is offset from the center of the channel as a function of a radius of curvature of the spiral channel.

8. The system as set forth in claim 1 wherein the spiral channel is a spiral wound structure.

9. The system as set forth in claim 1 wherein the spiral channel is a helical spiral structure.

10. A method for separating neutrally buoyant particles from a fluid, the method comprising:

receiving at least a portion of the fluid containing the neutrally buoyant particles at an inlet;

establishing a flow of the fluid in a spiral channel wherein the neutrally buoyant particles flow in a tubular band through the spiral channel in an asymmetric manner;

outputting the fluid within which the tubular band flows through a first outlet of the channel; and,

outputting the remaining fluid through a second outlet of the spiral channel;

wherein the fluid is received at an angle to facilitate the formation of the tubular band along an inner wall of the spiral channel.

11. The method as set forth in claim 10 further comprising establishing a second flow of the fluid through a second spiral channel nested with the spiral channel to narrow the tubular band.

12. The method as set forth in claim 11 further comprising establishing a flow of the remaining fluid in a second spiral channel cascaded with the first spiral channel to separate neutrally buoyant particles of a different size than the neutrally buoyant particles output through the first outlet.

13. The method as set forth in claim 10 further comprising establishing a flow of at least another portion of fluid in a second spiral channel.

14. The method as set forth in claim 10 further comprising re-circulating in the system at least a portion of the fluid output through the first outlet.

15. The method as set forth in claim 10 wherein the asymmetric manner of flow of the tubular band is a function of a radius of curvature of the spiral channel.

Claims

1. A system for separation of neutrally buoyant particles having the same density as a fluid from the fluid, the system comprising:

an inlet to receive at least a portion of the fluid containing the neutrally buoyant particles, wherein an inlet stream is angled toward an inner wall of side of the center of a spirals;

a spiral channel having a curvilinear channel geometry tailored to form in the fluid a tubular band by introducing a centrifugal force in the neutrally buoyant particles being offset to the side of the center of the spirals from a center of the channel, the tubular band flowing through the spiral channel in an asymmetric manner based on a balance of the centrifugal force, a wall lift and Saffman inertial lift, Magnus force, and inducement of a Dean vortex flow;

a first outlet for the fluid within which the tubular band flows; and,

a second outlet for the remaining fluid;

wherein the fluid is a liquid.

2. The system as set forth in claim 1 further comprising:

a second inlet connected to the second outlet of the spiral channel to receive the remaining fluid;

a second spiral channel within which the remaining fluid flows such that the remaining neutrally buoyant particles flow in a second tubular band offset to the side of the center of the spirals from the center of the second channel;

a third outlet for the fluid within which the second tubular band flows; and,

a fourth outlet for more remaining fluid.

3. A method for separating neutrally buoyant particles having the same density as a fluid from the fluid, the method comprising:

receiving at least a portion of the fluid containing the neutrally buoyant particles at an inlet, wherein an inlet stream is angled toward an

inner wall of side of the center of a spirals;

establishing a flow of the fluid in a spiral channel tailored to generate a tubular band in the fluid by introducing a centrifugal force in the neutrally buoyant particles , the tubular band offset to the side of the center of the spirals from a center of the channel flowing through the spiral channel in an asymmetric manner based on a balance of the centrifugal force, a wall lift and Saffman inertial lift, Magnus force, and the fluid force and inducement of a Dean vortex flow;

outputting the fluid within which the tubular band flows through a first outlet of the channel; and,

outputting the remaining fluid through a second outlet of the spiral channel;

wherein the fluid is a liquid.

4. The method as set forth in claim 3 wherein the flow of neutrally buoyant particles in a tubular band is adjustable as a function of fluid viscosity, average channel velocity, particle radius, fluid density, hydraulic diameter of the channel, angular velocity, and differential velocity across particles.