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 having a curvilinear channel geometry tailored to form in the fluid a tubular band having the neutrally buoyant particles flowing therein, the tubular band flow being through the channel in an asymmetric manner based on a balance of forces and inducement of a Dean vortex flow , wherein the flow of neutrally buoyant particles in the tubular band is a function of fluid viscosity, average channel velocity, particle radius, fluid density, hydraulic diameter of the channel, angular velocity, and differential velocity across particles;

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

a second outlet for the remaining fluid.

2. The system as set forth in claim 1 wherein the inlet is angled to facilitate earlier formation of the tubular band along an inner wall of the spiral channel.

3. 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.

4. 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 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.

5. The system as set forth in claim 4 wherein the remaining neutrally buoyant particles are of a different size than the neutrally buoyant particles output through the first outlet.

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

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

8. The system as set forth in claim 1 wherein the asymmetric manner of flow of the tubular band is a function of a radius of curvature of the spiral channel.

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

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

11. 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 tailored to generate a tubular band in the fluid having the neutrally buoyant particles flowing therein, the tubular band flowing through the spiral channel in an asymmetric manner based on a balance of forces and inducement of a Dean vortex flow, the flow of neutrally buoyant particles in the tubular band being 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;

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.

12. The method as set forth in claim 11 wherein the fluid is received at an angle to facilitate the formation of the tubular band along an inner wall of the spiral channel.

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

14. The method as set forth in claim 13 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.

15. The method as set forth in claim 11 further comprising establishing a flow of at least another portion of fluid in a second spiral channel.

16. The method as set forth in claim 11 further comprising re-circulating in the system at least a portion of the fluid output through the first outlet.

17. The method as set forth in claim 11 wherein establishing the asymmetric manner of flow of the tubular band is a function of a radius of curvature of the spiral channel.

18. 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 curved channel having a curvilinear channel geometry tailored to form in the fluid a tubular band having the neutrally buoyant particles flowing therein, the tubular band flow being through the channel in an asymmetric manner based on a balance of forces and inducement of a Dean vortex flow , wherein the flow of neutrally buoyant particles in the tubular band is a function of fluid viscosity,

average channel velocity, particle radius, fluid density, hydraulic diameter of the channel, angular velocity, and differential velocity across particles;

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

a second outlet for the remaining fluid.

19. A system comprising:

fluid having neutrally buoyant particles therein;

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

a curved channel having a tailored curvilinear channel geometry causing fluid flows such that the neutrally buoyant particles flow in a tubular band, the tubular band flow being through the channel in an asymmetric manner based on a balance of forces and inducement of a Dean vortex flow, wherein the flow of neutrally buoyant particles in the tubular band is a function of fluid viscosity, average channel velocity, particle radius, fluid density, hydraulic diameter of the channel, angular velocity, and differential velocity across particles;

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

a second outlet for the remaining fluid.

20. 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 curved channel tailored to generate a tubular band in the fluid having the neutrally buoyant particles flowing therein, the tubular band flowing through the channel in an asymmetric manner based on a balance of forces and inducement of a Dean vortex flow, the flow of neutrally buoyant particles in the tubular band being 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;

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 channel.

21. 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 tailored to generate a tubular band in the fluid having the neutrally buoyant particles flowing therein, the tubular band flowing through the spiral channel in an asymmetric manner;

adjusting the flow of neutrally buoyant particles in the tubular band 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;

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.

22. 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 curved channel tailored to generate a tubular band in the fluid having the neutrally buoyant particles flowing therein, the tubular band flowing through the channel in an asymmetric manner;

adjusting the flow of neutrally buoyant particles in the tubular band 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;

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 channel.

23. The system as set forth in claim 18 wherein the asymmetric manner of flow of the tubular band is a function of a radius of curvature of the channel.

24. The system as set forth in claim 19 wherein the asymmetric manner of flow of the tubular band is a function of a radius of curvature of the channel.