TITLE

MIXER SENSORS AND METHODS FOR USING SAME

BACKGROUND

[0001] The present disclosure generally relates to apparatuses for characterizing rheological properties of materials and methods for using same. More specifically, the present disclosure is directed to mixer sensors for rheological characterization of fluids having particles at various processing conditions.

[0002] Different types of rheological testing equipment have been widely available for use in laboratories, manufacturing plants, etc. for testing rheological characteristics of materials. Although apparatuses for testing rheological properties of materials are readily available in the art, they cannot always be used with every fluid requiring rheological characterization. For example, known apparatuses may not be suitable for use in characterizing fluids exposed to high temperature environments, such as aseptic processing systems. Additionally, known apparatuses may not be suitable for use with fluids having particulates. Indeed, most commercially available apparatuses require any particulates in a fluid to be strained, or otherwise removed, prior to rheological characterization. In this manner, the only portion of the sample left for characterization is the fluid portion, which may give a less accurate rheological measurement of the sample that may not reflect the actual processing conditions of the sample within the processing pipeline system.

[0002a] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or form part of common general knowledge in the field.

[0002b] It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

SUMMARY

[0002c] In a first aspect, the invention provides an apparatus for measuring rheological properties of a material, the apparatus comprising:

a drive head attachment so constructed and arranged to attach to one of a rheometer and viscometer;

a shaft comprising at least three blades arranged in an interrupted helical shape, wherein the plurality of blades are radially spaced about an axis of the shaft, wherein the drive head attachment is configured to receive a top end of the shaft therein, wherein one or more of the plurality of blades is curved, or is rotated about 20º to about 80º from horizontal, and wherein the plurality of blades are vertically spaced from each other by about 0.25 inches to about 1.25 inches; and

a base configured to receive an end of the shaft, and wherein the base further comprises at least one o-ring groove configured to accept an o-ring seal and wherein the base is configured to receive a bottom end of the shaft.

[0002d] In a second aspect, the invention provides a system for measuring rheological properties of a material, the system comprising:

a device comprising a stationary measurement cup and an impeller drive head; and

an impeller attached to the impeller drive head, the impeller comprising:

a shaft comprising at least three blades arranged in an interrupted helical shape; and

a base configured to receive an end of the shaft, wherein the device is one of rheometer and a viscometer.

[0002e] In a third aspect, the invention provides a method for measuring rheological properties of a material, the method comprising the step of:

providing a device comprising a stationary cylinder filled with the material and a rotatable sensor drive head;

attaching a sensor to the rotatable sensor drive head, the sensor comprising a shaft comprising at least three blades arranged in an interrupted helical shape, and

a base configured to receive an end of the shaft;

inserting the sensor into the stationary cylinder; and

rotating the sensor, wherein the device is one of a rheometer and viscometer.

[0002f] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive; that is to say, in the sense of “including, but not limited to”.

[0003] The present disclosure provides apparatuses for use with measuring rheological properties of a material and methods for using same. In a general embodiment, an apparatus for measuring rheological properties of a material is provided. The apparatus includes a shaft comprising at least three blades arranged in an interrupted helical shape and a base configured to receive an end of the shaft.

[0063] Another advantage of the present disclosure is to provide mixer sensors that provide rheological measurements that closely simulate actual processing conditions.

[0064] Yet another advantage of the present disclosure is to provide mixer sensors that can accurately characterize the rheological properties of fluids having particulates.

[0065] Still yet another advantage of the present disclosure is to provide mixer sensors that help to prevent settling of particulates in sample fluids during rheological characterization.

[0066] Another advantage of the present disclosure is to provide replaceable mixer sensors that may be attached to different rheometer drive heads.

[0067] Yet another advantage of the present disclosure is to provide different mixer sensors that may be attached to the same rheometer drive head.

[0068] Still yet another advantage of the present disclosure is to provide mixer sensors that are configured to be used in conditions spanning a wide range of temperatures and a wide range of shear rates.

[0069] Additional features and advantages are described herein, and will be apparent from, the following Detailed Description.

[0069a] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to.”

BRIEF DESCRIPTION OF THE FIGURES

[0070] FIG. 1 is a perspective view of a mixer sensor in accordance with an embodiment of the present disclosure.

[0071] FIG. 2 is a top view of a particle screen in accordance with an embodiment of the present disclosure.

[0072] FIG. 3 is a perspective view of a mixer sensor and a particle screen in accordance with an embodiment of the present disclosure.

[0073] FIG. 4 is a perspective view of a mixer sensor in accordance with an embodiment of the present disclosure.

[0074] FIG. 5 is a top view of the mixer sensor of FIG. 4 in accordance with an embodiment of the present disclosure.

CLAIMS

~~The invention is claimed as follows:~~

1. An apparatus for measuring rheological properties of a material, the apparatus comprising:

a drive head attachment so constructed and arranged to attach to one of a rheometer and a viscometer;

a shaft comprising at least three blades arranged in an interrupted helical shape, wherein the plurality of blades are radially spaced about an axis of the shaft, wherein the drive head attachment is configured to receive a top end of the shaft therein, wherein one or more of the plurality of blades is curved, or ~~wherein each of the plurality of blades~~ is rotated about 20º to about 80º from horizontal, and wherein the plurality of blades are vertically spaced from each other by about 0.25 inches to about 1.25 inches; and

a base configured to receive an end of the shaft, and wherein the base further comprising at least one o-ring groove configured to accept an o-ring seal and wherein the base is configured to receive a bottom end of the shaft.

2. The apparatus according to ~~C~~claim 1, wherein at least one of the shaft, the base, the drive head attachment, is manufactured from a material selected from the group consisting of steel, steel alloys, stainless steel, chromium, cobalt-chromium, and combinations thereof.

3. The apparatus according to claim 1 or ~~C~~claim 2, wherein the material is cobalt-chromium.

4. The apparatus according to any one of claims 1 to 3 ~~Claim 1~~, wherein the plurality of blades are ~~arranged in an interrupted helical shape, and~~ radially spaced from each other by about 45º to about 135º.

5. The apparatus according to any one of the preceding claims, ~~Claim 1,~~ wherein each of the plurality of blades is substantially triangularly shaped.

6. The apparatus according to any one of the preceding claims, ~~Claim 1,~~ wherein the base is further configured to mate with a particle screen, wherein the particle screen comprises an open center portion that is configured to receive the base, and wherein the particle screen comprises a diameter from about 1 to about 3 inches.

7. The apparatus according to ~~C~~claim 6, wherein the particle screen is substantially circular in shape and further comprises a plurality of holes between the center portion and the circumference.

8. The apparatus according to claim 7 ~~any one of Claim 6~~, wherein the particle screen rests on a plurality of pegs that are formed integrally with particle screen or are friction fit into the holes of particle screen.

9. The apparatus according to any one of the preceding claims, ~~Claim 6,~~ further comprising a temperature probe, wherein the temperature probe is configured to extend through at least one of the holes of the particle screen.

10. The apparatus according any one of the preceding claims, ~~to Claim 1,~~ wherein at least two of the at least three blades attached to the shaft are curved blades, each curved blade comprising three sections. ~~is:~~

~~at least two curved blades attached to the shaft, each curved blade comprising three sections; and~~

~~at least two linear blades attached to the shaft.~~

11. The apparatus according to any one of the preceding claims further comprising at least two linear blades attached to the shaft.

~~11~~12. The apparatus according to ~~C~~claim 10 or claim 11, wherein each of the three sections are separated by a space.

~~12~~13. The apparatus according to any one of claims 10 to 12, ~~Claim 10,~~ wherein each of the three sections are equal in length.

~~13~~14. The apparatus according to any one of claims 11 to 13, ~~Claim 10,~~ wherein the linear blades are surface scraper blades.

~~14~~15. The apparatus according to any one of claims 11 to 14, ~~Claim 10,~~ wherein each of the linear blades is attached to the shaft at a top end and a bottom end of the linear blade.

~~15~~16. The apparatus according to any one of claims 11 to 15, ~~Claim 10,~~ wherein each of the linear blades has a length from about 1.5 inches to about 3.5 inches.

~~16~~17. The apparatus according to any one of claims 11 to 16, ~~Claim 10,~~ wherein each of the linear blades comprises a step-shape forming two different parallel portions of the linear blade, wherein the first parallel portion of the linear blade has a length from about 0.1 to about 0.2 inches and wherein the second parallel portion of the linear blade has a length from about 0.2 inches to about 0.6 inches.

~~17. The apparatus according to Claim 1, wherein:~~

~~the shaft comprising at least three blades comprises a first and second pairs of blades and an inverted cone, wherein each of the first pair of blades are oriented substantially vertically, wherein each of the second pair of blades are oriented at an acute angle with respect to a horizontal plane, wherein each of the first pair of blades has a width from about 10 to 15 mm, and wherein the cone forms an angle with the shaft from about 15º to about 45º.~~

~~18. The apparatus according to Claim 17, wherein the first pair of blades and the second pair of blades are each radially spaced about an axis of the shaft.~~

~~19. The apparatus according to Claim 17, wherein the first pair of blades and the second pair of blades are each radially spaced from each other by about 180º.~~

~~20. The apparatus according to Claim 17, wherein the first pair of blades are vertically spaced from each other such that a bottom side of a first blade is at the same vertical height as a top side of a second blade.~~

~~21. The apparatus according to Claim 17, wherein the first pair of blades and the second pair of blades are individually comprise a shape selected from the group consisting of rectangle, square, and combinations thereof.~~

~~22. The apparatus according to Claim 17, wherein the first pair of blades are located at a bottom portion of the shaft.~~

~~23. The apparatus according to Claim 17, wherein the second pair of blades are located in substantially the same horizontal plane.~~

~~24. The apparatus according to Claim 17, wherein the inverted cone is located at a top portion of the shaft.~~

~~25~~18. A system for measuring rheological properties of a material, the system comprising:

a device comprising a stationary measurement cup and an impeller drive head; and

an impeller attached to the impeller drive head, the impeller comprising

a shaft comprising at least three blades arranged in an interrupted helical shape; and

a base configured to receive an end of the shaft, wherein the device is one of a rheometer and a viscometer.

~~26~~19. The system according to ~~C~~claim ~~25~~18, further comprising a fluid contained within the measurement cup.

~~27~~20. The system according to ~~C~~claim 18 or claim 19 ~~26~~, wherein the fluid comprises particulates.

~~28~~21. The system according to any one of claims 18 to 20, ~~Claim 25,~~ wherein the stationary measurement cup comprises a stationary particle screen at a bottom of the cup.

~~29~~22. The system according to any one of claims 18 to 21, ~~Claim 25,~~ wherein the stationary measurement cup comprises an integral temperature probe.

~~30~~23. The system according to any one of claims 18 to 22,~~Claim 25,~~ wherein ~~the~~ at least two of the three blades ~~is at least two curved blades~~ attached to the shaft are curved blades, each curved blade comprising three sections., ~~and at least two linear blades attached to the shaft.~~

24. The system according to any one of claims 18 to 23, wherein the shaft further comprises at least two linear blades.

~~31. The system according to Claim 25, wherein the shaft comprising at least three blades is a shaft comprising first and second pairs of blades and an inverted cone, wherein each of the first pair of blades are oriented substantially vertically, and wherein each of the second pair of blades are oriented at an acute angle with respect to a horizontal plane.~~

~~32~~25. A method for measuring rheological properties of a material, the method comprising the steps of:

providing a device comprising a stationary cylinder filled with the material and a rotatable sensor drive head;

attaching a sensor to the rotatable sensor drive head, the sensor comprising a shaft comprising at least three blades arranged in an interrupted helical shape, and

a base configured to receive an end of the shaft;

inserting the sensor into the stationary cylinder; and

rotating the sensor, wherein the device is one of a rheometer and a viscometer.

~~33~~26. The method according to ~~Claim 32~~claim 25, wherein the material is a fluid.

~~34~~27. The method according to ~~Claim 32~~claim 26, wherein the fluid comprises particulates.

~~35~~28. The method according to ~~Claim 32~~claims 26 or 27, further comprising sensing a temperature of the fluid with a temperature probe.

~~36~~29. The method according to any one of claims 25 to 28,~~Claim 32,~~ further comprising placing a stationary particle screen at a bottom of the stationary cylinder.

~~37~~30. The method according to any one of claims 25 to 29,~~Claim 32,~~ wherein at least two of the at least three blades ~~is at least two curved blades~~ attached to the shaft are curved blades, each curved blade comprising three sections, and the shaft further comprising at least two linear blades attached to the shaft; the method further comprising the steps of:~~, and~~

~~at least two linear blades attached to the shaft;~~

inserting the sensor into the stationary cylinder; and

rotating the sensor.

~~38~~31. The method according to ~~Claim 37~~claim 30, further comprising rotating the sensor at different angular velocities.

~~39. The method according to Claim 32, wherein the shaft comprising at least three blades is a shaft comprising first and second pairs of blades and an inverted cone, wherein each of the first pair of blades are oriented substantially vertically, and wherein each of the second pair of blades are oriented at an acute angle with respect to a horizontal plane;~~

~~inserting the sensor into the stationary cylinder; and~~

~~rotating the sensor.~~

~~40. The method according to Claim 32, further comprising rotating the sensor at different angular velocities.~~