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- 1 -

GENERATION OF FINE BUBBLES

The present invention is directed toward the introduction of gas into a liquid ambient in such a way as to generate smaller gas bubble sizes at gas to liquid ratios greater than heretobefore possible.

The chemical industry utilizes numerous processing techniques in which intimate contact of physically disparate phases is of necessity promoted to optimize the chemical reactions sought to be achieved. Typically, these reactions take place in the liquid phase, and consequently a wide variety of devices have been developed for dispersing gases in liquids.

In typical gas-liquid reactors, a gas is introduced into the bottom of a reactor through an open-ended standpipe, a horizontally perforated pipe, a perforated plate, or a perforated sparge ring. At ordinary gas rates, the size of the bubble generated is relatively large, for example in the range of about 1/4 inch (6.4 mm) to about 1 inch (2.54 cm) in diameter, for orifice sizes in the range of from about 1/4 to 1 inch (6.4 mm to 2.54 cm).

Aspirators also have been used for dispersing a gas in a liquid. In these types of devices a liquid is pumped at a rapid rate through a nozzle and the gas is aspirated through a venturi, for example, and thereby dispersed in a liquid stream. In such systems, however, the gas to liquid ratio generally is low, for example, up to about 1:1.

According to the invention from one aspect there is provided a method for generating gaseous bubbles in a liquid ambient, comprising: forcing a gas through, and along the axis of, one (or more) orifice(s) located in the liquid ambient while simultaneously forcing a liquid through, and along the axis of, a respective opposed orifice (or respective, opposed, orifices) within the liquid ambient so that the axial stream of liquid intersects the axial gas stream within the liquid ambient at a velocity sufficient to generate local shear fields whereby gas bubbles are generated that have a diameter smaller than gas bubbles formed when no liquid is ejected at said velocity.

In this way, the production of fine bubbles is permitted even at high volumetric gas flow to liquid flow ratios; i.e., at volumetric gas flow to liquid flow ratios ranging from 1:1 to 20:1 or more.

According to the invention from another aspect there is provided a liquid-gas contacting apparatus comprising:

a vessel for containing a liquid;

a gas conduit having at least one gas orifice located in said vessel so that said orifice(s) will be in a column of liquid under conditions of use;

a liquid conduit having a liquid orifice for each gas orifice located in said vessel so that the orifice(s) will be in a column of liquid under conditions of use, said orifice(s) being positioned so as to be substantially co-planar with, and opposed at an angle

of from 20° to 160° to, the respective or a respective gas orifice(s);

means for forcing gas through, and along the axis of, said gas orifice(s); and

means for forcing liquid through, and along the axis of, said liquid orifice(s), so that the axial stream of liquid intersects the axial stream of gas within the liquid ambient at a velocity sufficient to shear the gas, whereby gaseous bubbles will be generated and flow upwardly in contact with a liquid in said vessel, the bubbles generated having a diameter smaller than the gas bubbles formed when no liquid is ejected at said velocity.

The method and apparatus defined above, of course, have wide applicability to the intimate contacting of liquid and gaseous phases. Thus, in a particularly preferred embodiment of the present invention, a gas liquid mixing device is provided in which concentric ring-type spargers are positioned in a mixing vessel for separately introducing, in a liquid ambient, a liquid and a gas stream into the vessel. The orifices in the spargers are opposed so that the liquid and gas emitted from the orifices create a high localized shear field at the gas sparger orifices, thereby generating bubbles that are finer than what would be generated in the absence of the shear field. Preferably, recycled liquid is used in the liquid sparger.

The present invention will be more readily understood upon reading the following description given by way of example and with reference to the accompanying drawings, wherein:-

Figure 1 is a schematic illustration of one form of bubble generator in accordance with the present invention.

Figure 2 is a schematic illustration of another form of a bubble generator in accordance with the present invention.

Figure 3 is a schematic sectional view, partly in perspective, illustrating a double ring sparger bubble generator in accordance with the present invention.

Figure 4 is a side view of an embodiment of the present invention illustrating a double sparger arrangement, including means for recirculating liquid from the liquid ambient of the liquid sparger.

The drawings illustrate a variety of bubble generator configurations in which two fluids are forced, one a gas and the other a liquid, through separate conduits, each having an equal number of opposed orifices so the liquid ejected from the liquid orifices generates localized shear fields at the gas orifices, thereby producing fine, uniformly sized gaseous bubbles in a surrounding liquid ambient.

Figure 1 shows open-ended conduits 12 and 14, respectively which are arranged within a contacting vessel or a reactor 10. As shown, an equal number of one or more orifices 15 and 16 of conduits 12 and 14,

respectively, are opposed so that localized shear fields will be generated at the orifices. Thus, in general, the orifices are so opposed as to be at an angle of from about 20° to about 160° with respect to each other. Preferably, the orifices are planar and orthogonally opposed, i.e. at about 90° with respect to each other. The conduits are located near the bottom of the liquid ambient column so that the gas introduced into the liquid medium via conduit 12 will flow upwardly through the liquid ambient. Means are provided (not shown) for forcing a gaseous stream through conduit 12 for ejection through orifice 15. Similarly, means are provided for forcing a liquid stream through conduit 14 for ejection through orifice 16. The liquid forced through conduit 14 may be the same or a different liquid from the liquid of the liquid ambient. Typically, the conduit will have orifices arranging in size from about $1/8$ inch (3.2 mm) to about 4 inches (10.2 cm) in diameter.

The flow rates of both gas and liquid through the conduits may be controlled by valves, pumps and the like. Importantly, the liquid is ejected from the orifice at a velocity sufficient to generate local shear fields at the gas orifice, thereby generating finer gaseous bubbles than would otherwise form when gas is emitted from the gas orifice. Typically, liquid is ejected from the liquid orifice at velocities in the range of about 10 ft/sec (3.0 m/sec) to greater than about 30 ft/sec (9.1 m/sec) while gas is emitted from the gas orifices at velocities of about 5 ft/sec (1.5 m/sec) to about 100 ft/sec (30.5 m/sec). In a very typical operation, liquid is ejected through the liquid orifices at about 20 ft/sec (6.1 m/sec) while gas is ejected through the gas orifices at about 75 ft/sec (22.9 m/sec).

In some instances, it will be preferred to have the gas orifice be significantly larger than the liquid orifice. For example, the ratio of gas orifice area to liquid orifice area may be in the range of from about 1:1 to about 5:1. In this regard, see especially Figure 2, which shows rectangular gas and liquid conduits 22 and 24, respectively. The orifices in the Figure 2 embodiment are rectangular in shape, as can be readily seen. Indeed, as shown, the gas orifice has a significantly larger area than the orifice for the liquid conduit 24. Both conduits, of course, are co-planar and orthogonally arranged. The larger area for the gas orifice permits discharging gas at lower velocities into the liquid ambient, but nonetheless at flow rates that are greater than the liquid flow rate from conduit 24.

In the embodiment shown in Figure 3, two concentric tubular rings 32 and 34 are provided with a plurality of orifices 36 and 38. As can be seen, the orifices are aligned so as to be orthogonally disposed with respect to each other. Ring 32 as shown is for the gas stream and ring 34 is for the liquid stream.

Figure 4 shows ring-type spargers 42 and 44 located in the bottom of a column of ambient liquid contained, for example, in a contactor or a reactor having cylindrical sidewalls 10. The orifices 46 and cylindrical sparger 42 are aligned relative to the orifices 48 and the cylindrical liquid sparger 44 so as to be orthogonal with respect to each other. Gas is fed to sparger 42 and is injected into the liquid ambient via orifices 46. Liquid is pumped through the ring sparger 44, vents through orifices 48 at velocities sufficient to shear the gas being injected

from sparger 42, thereby generating fine, uniform gaseous bubbles.

As is shown in Figure 4, a conduit 47 communicates with ring sparger 44 via distributor arms 45 which extend radially from conduit 47. In a particularly preferred embodiment, liquid is recycled from the liquid ambient column via conduit 47 for shearing the gas ejected via orifices 46. Means are also provided for deploying gas to ring 42 such as arms 49.

In a particularly preferred embodiment of the present invention, the bubble ring sparger is located in a bubble or drop column.

The following example will further illustrate the significant features of one embodiment of the present invention.

EXAMPLE

This example illustrates the advantages of one form of bubble generator in accordance with the present invention. For this demonstration, a 3 foot (0.9 m) diameter tank containing water was used. The tank was equipped to recirculate the water. Also, at the bottom of the tank two concentric rings were provided for introducing gas and liquid, respectively. The outer ring had slots 1/2 inch (1.3 cm) high by 1/8 inch (0.3 cm) wide facing inwardly through which gas entered the tank. The inner ring had slots 1/4 inch (6.3 mm) long and 1/8 inch (3.2 mm) wide orthogonally disposed with respect to the gas slots, for introducing shearing liquid. Gas was fed through the gas ring at 150 SCF/min (4248 litres/min) and liquid through the liquid ring at 50 gal/min (189.3 litres/min) to 100 gal/min (378.5 litres/min). After a steady state was reached, the gas and liquid flows to the bubble generator were shut off. Simultaneously, a video record was made of the drop in the level of the tank's contents. Using standard techniques, an analysis of the drop in level as a function of time yielded estimates of the bubble size distribution. The steady state level indicated the average gas hold-up during operation.

Comparative data was obtained following the proceeding steps but not introducing shearing liquid. It was established that the bubble generator reduced the bubble size from 0.42 mm to 0.34 mm while it increased the average gas hold-up from 24.8% to 29.6%.

CLAIMS:

1. A method for generating gaseous bubbles in a liquid ambient, comprising: forcing a gas through, and along the axis of, one (or more) orifice(s) located in the liquid ambient while simultaneously forcing a liquid through, and along the axis of, a respective, opposed orifice (or respective, opposed, orifices) within the liquid ambient so that the axial stream of liquid intersects the axial gas stream within the liquid ambient at a velocity sufficient to generate local shear fields whereby gas bubbles are generated that have a diameter smaller than gas bubbles formed when no liquid is ejected at said velocity.

2. A method as claimed in claim 1, wherein said liquid is ejected at a velocity in the range of from 10 ft/sec (3.0 m/sec) to greater than 30 ft/sec (9.1 m/sec) and wherein said gas is ejected at a velocity of from 5 ft/sec (1.5 m/sec) to 100 ft/sec (30.5 m/sec).

3. A method as claimed in claim 1 or 2, wherein the ratio of the gas to ejected liquid volume is in the range of from 1:1 to greater than 20:1.

4. A method as claimed in claim 1, wherein the gas is ejected into a liquid column through orifices in a gas distributor and wherein the liquid is ejected through orifices that are opposed to the gas orifices at an angle of from 20° to 160°.



5. A method as claimed in claim 4, wherein said liquid is ejected at a velocity in the range of from 10 ft/sec (3.0 m/sec) to greater than 30 ft/sec (9.1 m/sec).

6. A method as claimed in claim 4 or 5, wherein said gas is ejected at a velocity of from 5 ft/sec (1.5 m/sec) to 100 ft/sec (30.5 m/sec).

7. A method as claimed in claim 4, 5 or 6, wherein the ratio of the gas to ejected liquid volume is in the range of from 1:1 to 20:1.

8. A liquid-gas contacting apparatus comprising:

a vessel for containing a liquid;

a gas conduit having at least one gas orifice located in said vessel so that said orifice(s) will be in a column of liquid under conditions of use;

a liquid conduit having a liquid orifice for each gas orifice located in said vessel so that the orifice(s) will be in a column of liquid under conditions of use, said orifice(s) being positioned so as to be substantially co-planar with, and opposed at an angle of from 20° to 160° to, the respective or a respective said gas orifice(s);

means for forcing gas through, and along the axis of, said gas orifice(s); and



means for forcing liquid through, and along the axis of, said liquid orifice(s), so that the axial stream of liquid intersects the axial stream of gas within the liquid column at a velocity sufficient to shear gas, whereby gaseous bubbles will be generated and flow upwardly in contact with the liquid in said vessel, the bubbles generated having a diameter smaller than the gas bubbles formed when no liquid is ejected at said velocity.

9. Apparatus as claimed in claim 8, wherein the or each said liquid orifice is opposed at an angle of 90° to the or each respective said gas orifice.

10. Apparatus as claimed in claim 8 or 9, wherein the gas conduit is a ring sparger and said liquid conduit is a concentrically located ring sparger.

