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INVESTIGATIONS OF GAS HOLD UP IN BAFFLED REVERSED FLOW JET LOOP REACTOR

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Abstract: *Gas–liquid contactors play an essential role in numerous chemical, biochemical, petrochemical, and environmental processes because of their ability to enhance mass transfer between phases. Among these contactors, the Baffled Reversed Flow Jet Loop Reactor (BRFJLR) offers superior gas dispersion, higher turbulence, improved liquid circulation, and enhanced gas residence time compared to conventional bubble columns and jet loop reactors. In the present study, the hydrodynamic behavior of a BRFJLR was investigated by evaluating gas holdup, which is one of the most important parameters governing reactor performance and mass transfer efficiency. Experimental investigations were carried out using a gas–liquid two-phase system comprising compressed air as the gas phase and aqueous solutions .The effects of gas flow rate, liquid flow rate, nozzle diameter, nozzle immersion height, nozzle position (concentric and eccentric), alcohol concentration, and liquid properties on gas holdup were systematically examined. Gas holdup was determined experimentally by measuring the reduction in liquid height after stopping the gas and liquid supply under steady-state operating conditions. The results demonstrated that gas holdup increased with increasing gas flow rate, liquid flow rate, alcohol concentration, and nozzle immersion height. The smaller nozzle diameter (18.7 mm) produced higher gas holdup than the larger nozzle because of increased jet velocity and improved gas dispersion. Furthermore, the concentric nozzle arrangement provided higher gas holdup than the eccentric arrangement due to more uniform flow circulation. Among the investigated liquids, n-butanol exhibited the maximum gas holdup, particularly at higher concentrations and operating flow rates, owing to its higher viscosity and favorable hydrodynamic characteristics. The findings indicate that the baffled reversed flow jet loop reactor provides efficient gas–liquid contact and can be effectively employed in biochemical reactors, fermentation systems, wastewater treatment processes, and other industrial applications requiring enhanced mass transfer.*

Key Words: *Baffled Reversed Flow Jet Loop Reactor (BRFJLR); Gas Holdup; Gas–Liquid Hydrodynamics; Jet Loop Reactor; Draft Tube Reactor; Air–Liquid Two-Phase Flow; Nozzle Diameter; Nozzle Immersion Height.*

1. INTRODUCTION:

Gas-liquid reactors are extensively used in chemical, petrochemical, biochemical, fermentation, and wastewater treatment industries because they provide efficient mixing and high mass transfer rates. Among these reactors, the **Reversed Flow Jet Loop Reactor (RFJLR)** has attracted attention due to its superior gas-liquid contact, improved circulation, and enhanced gas residence time.

A RFJLR consists of a reactor column with a centrally located draft tube and a two-fluid nozzle. Unlike conventional jet loop reactors, gas is introduced from the top into a downward-flowing liquid stream. Since the gas bubbles move opposite to their natural buoyancy, their residence time inside the reactor increases significantly. This results in higher gas holdup, improved turbulence, and better mass transfer efficiency.

The addition of baffles further improves reactor performance by enhancing circulation, reducing vortex formation, and increasing mixing efficiency. These characteristics make the reactor highly suitable for wastewater treatment, fermentation, biochemical processing, hydrogenation, and other gas-liquid operations.

2. LITERATURE REVIEW:

The literature survey explains that conventional bubble columns often suffer from poor gas distribution, lower circulation, and reduced gas residence time. Airlift reactors improve circulation but still have limitations in handling slurry systems. Jet loop reactors offer:

- High turbulence
- Excellent gas dispersion
- Higher volumetric mass transfer coefficient
- Lower power consumption

However, conventional jet loop reactors may experience:

- nozzle blockage
- lower gas residence time
- reduced efficiency with sparingly soluble gases.

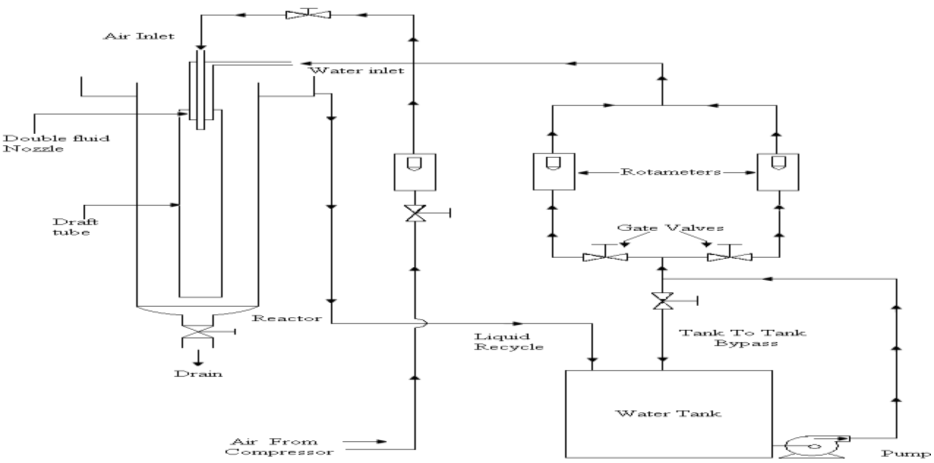
The Reversed Flow Jet Loop Reactor overcomes these drawbacks by forcing gas bubbles downward against buoyancy, thereby increasing contact time between gas and liquid. Previous researchers reported that reactor hydrodynamics strongly depend on:

- liquid flow rate
- gas flow rate
- nozzle diameter
- nozzle height
- reactor geometry

3. OBJECTIVES :

- To investigate gas holdup in a baffled Reversed Flow Jet Loop Reactor.
- To study the influence of liquid flow rate on gas holdup.
- To evaluate the effect of gas flow rate on reactor performance.
- To determine the influence of nozzle diameter on gas holdup.
- To study the effect of nozzle immersion height.
- To compare concentric and eccentric nozzle positions.

4. RESEARCH METHOD :



Experimental observations were analyzed by plotting:

- Gas holdup vs. liquid flow rate
- Gas holdup vs. gas flow rate
- Gas holdup vs. superficial liquid velocity
- Concentric nozzle
- Eccentric nozzle

The effects of nozzle diameter and immersion height were also analyzed graphically to identify conditions producing maximum gas holdup.

(Ethanol, 0.01%, 18.7 mm, H = 25 cm, concentric)

Gas holdup increased from 0.276% at Qg = 5, Ql = 20 to 4.47% at Qg = 30, Ql = 100, representing about a 16-fold increase.

At constant gas flow (Qg = 30), increasing liquid flow from 20 to 100 increased gas holdup from 0.69% to 4.47%.
At constant liquid flow (Ql = 100), increasing gas flow from 5 to 30 increased gas holdup from 1.43% to 4.47%.
The graph confirms an almost monotonic increase in gas holdup with both gas and liquid flow rates.

4.1 Effect of Nozzle Diameter (18.7 mm vs 38.9 mm)

Two nozzle diameters, **18.7 mm** and **38.9 mm**, were investigated to evaluate their influence on gas holdup in the baffled reversed flow jet loop reactor.
The experimental results clearly indicate that the **18.7 mm nozzle produced consistently higher gas holdup** than the **38.9 mm nozzle** under identical operating conditions. The smaller nozzle generated a higher liquid jet velocity due to the reduced flow area. The high-velocity jet entrained a larger quantity of air into the reactor, producing finer bubbles and more uniform gas dispersion throughout the reactor.
In contrast, the larger nozzle produced relatively coarse bubbles because of its lower exit velocity. The lower turbulence resulted in reduced gas dispersion and shorter bubble residence time, thereby decreasing the overall gas holdup.

Discussion

- Smaller nozzle diameter → higher jet velocity
- Higher jet velocity → stronger air entrainment
- Stronger air entrainment → increased turbulence
- Increased turbulence → finer bubbles
- Finer bubbles → longer gas residence time
- Longer residence time → higher gas holdup

The experimental observations demonstrate that reducing nozzle diameter significantly improves reactor hydrodynamics and mass transfer performance. Consequently, the **18.7 mm nozzle was found to be the optimum configuration** for achieving maximum gas holdup.

4.2 Effect of Nozzle Position (Concentric vs Eccentric)

Two nozzle configurations were studied:

- Concentric nozzle
- Eccentric nozzle

The concentric nozzle consistently produced higher gas holdup than the eccentric nozzle.
In the concentric arrangement, the liquid jet entered the draft tube symmetrically, generating a uniform circulation pattern throughout the reactor. The bubbles remained suspended for a longer duration because of the stable circulation loop.
In the eccentric configuration, the jet became asymmetric, causing uneven liquid circulation and localized turbulence. Bubble coalescence increased and gas escaped more rapidly from the reactor, reducing gas holdup.

Experimental observations

- Concentric nozzle generated maximum gas holdup.
- Eccentric nozzle showed comparatively lower gas holdup.
- Bubble distribution was more uniform in concentric flow.
- Pressure losses were lower in concentric arrangement.

These observations indicate that the **concentric nozzle provides superior hydrodynamic characteristics** and should be preferred for industrial operation.

4.3 Effect of Nozzle Immersion Height

Three immersion heights were investigated:**25 cm** ,**50 cm** and **70 cm**
The results indicate that gas holdup increased continuously with increasing immersion height.
25 cm immersion: At the lowest immersion height, bubbles travelled only a short distance before escaping. The residence time was comparatively low, resulting in lower gas holdup.
50 cm immersion: Increasing immersion height increased the bubble travel distance. Consequently, bubble residence time increased and gas holdup improved considerably.
70 cm immersion: The highest immersion depth produced the maximum gas holdup because the gas bubbles travelled through almost the entire reactor height before reaching the free surface.
Longer residence time allowed:greater bubble dispersion ,better liquid circulation ,improved gas-liquid contact and increased turbulence.
Thus, the **70 cm immersion height provided the highest reactor efficiency**.

4.4 Analysis of Graph: % Gas Holdup vs Liquid Flow Rate (QL)

The graph of **% gas holdup versus liquid flow rate** shows that gas holdup increased steadily as liquid flow rate increased.

At low liquid flow rates, circulation inside the reactor was weak. Gas bubbles rose rapidly because of buoyancy, producing relatively low gas holdup.

As liquid flow rate increased:

- jet momentum increased
- turbulence increased
- air entrainment improved
- bubble breakup increased
- bubble residence time increased

4.5 Analysis of Graph: % Gas Holdup vs Superficial Liquid Velocity

The superficial liquid velocity graph demonstrates that increasing liquid velocity enhances gas holdup.

Higher superficial velocity results in:

- greater kinetic energy
- improved mixing
- higher turbulence
- smaller bubbles
- better gas dispersion

Initially, gas holdup increases rapidly with velocity.

At higher velocities, the rate of increase becomes smaller because bubble breakup and coalescence begin approaching equilibrium.

Therefore, the graph exhibits an increasing trend with a gradually decreasing slope at high velocities.

This behaviour is consistent with gas-liquid hydrodynamic theory.

4.6 Analysis of Graph: % Gas Holdup vs Gas Flow Rate (Qg)

The graph of gas holdup against gas flow rate shows a continuous increase in gas holdup with increasing gas flow.At low gas flow:

- fewer bubbles entered the reactor
- gas dispersion remained limited
- gas holdup was comparatively low

As gas flow increased:

- bubble generation increased
- interfacial area increased
- bubble residence time increased
- overall gas volume inside reactor increased

The graph indicates an almost linear increase throughout the investigated range.

However, at the highest gas flow rates, the increase became slightly smaller because of increased bubble coalescence.

Overall, increasing gas flow improved reactor performance by increasing the available gas-liquid interfacial area for mass transfer.

5. FINDINGS :

The experimental investigation produced several important observations:

- Smaller nozzle diameter (18.7 mm) generated higher gas holdup because the liquid velocity increased as nozzle diameter decreased.
- Increasing gas flow rate increased gas holdup due to greater bubble generation.
- Increasing liquid flow rate improved circulation and enhanced gas dispersion.
- Larger nozzle immersion heights increased gas residence time, resulting in higher gas holdup.
- Concentric nozzle arrangements performed better than eccentric arrangements because the flow was less obstructed.
- Increasing alcohol concentration increased gas holdup because solution viscosity and density increased.

6. CONCLUSION:

From the whole experimental work we conclude that the solutions of methanol, ethanol and n-butanol have different gas holdups and we get maximum gas holdup for n-butanol at high concentration and high liquid and gas flow rates with high immersion height. So the n-butanol is suitable for bioreaction in baffled reversed flow jet loop reactor.

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