

“Study of average circulation velocity of fluids in baffled reversed flow Jet loop reactor”

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ABSTRACT: Jet loop Bioreactors (JLBR) are being widely applied in a number of chemical, Biochemical, Petroleum refineries and Petrochemical industries for the treatment of the waste water. Some of the advantages of the system are simple in construction & operation, low investments & operational cost as well as very fine gas dispersion and high mixing & mass transfer performance. In JLBR circulation and fluid dispersion are achieved by a liquid jet. Liquid is injected into the reactor with high velocity causing a fine dispersion of different phases. In down flow jet loop reactors the driving gas is introduced from top of the reactor into a liquid flowing co currently downward so that the gas bubbles are forced to move in a direction opposite to their buoyancy. The reactor consists of a vertical column. A draft tube was placed axially in the centre of the reactor. The spray nozzle is located inside the draft tube.

Mixing Characteristics in JLBR will be studied by using conductivity cell with the tracer particle or Photographic techniques. To study of the hydrodynamic behavior of fluid flow inside the reactor, effects of various parameters like liquid flow rate, gas flow rate Nozzle diameter, Nozzle heights etc on mixing characteristics are planned to study.

Keywords: *Jet loop Bioreactor, tracer particles, immersion height, Digital Image processing, Average Circulation Velocity determination, Three phase system, baffled RFJLR*

1. INTRODUCTION:

Conventional biological treatment processes have been used for many years in the treatment of industrial and domestic wastewaters. However, these processes have some disadvantages such as larger area requirement, necessity of the transportation of wastewater to the unpopulated areas due to odour and other emission problems.

For this reason, some studies have been carried out to develop smaller and faster wastewater treatment systems. The use of Jet loop Bioreactor and airlift reactors coupled with membrane filtration may be seen as examples of such an approach. Among the

different types of loop reactors, it was found that the reactors where the mixing and flow circulation are achieved through jet flows had improved performance characteristics (Padmavathi and RemanandaRao, 1991). This type of loop reactors, normally referred as jet loop reactors (JLRs), has become increasingly important in conducting chemical and biochemical reactions.

A JLR is basically an assembly of two concentric cylinders of which the inner one is known as “draft tube” and the outer one as “reactor”. A two-fluid nozzle (liquid and gas), also usually with a structure of concentric cylinders, disperses the gas delivered in one of the tubes by means of the liquid jet delivered in the other tube (Dirix and Wiele, 1990; Velan and Ramanujam, 1991, 1992a,b). If wished, the liquid and the gas from their respective reactor exits can be recirculated back to reactor through the two fluid nozzles until the liquid is saturated with the gas. JLRs have found applications in wastewater treatment processes due to their high mass transfer rates as well as their intrinsic high turbulence characteristics which also result in the disintegration of large biomass aggregates thus creating a very large surface area for greater microbial activity. Aeration efficiency of conventional activated sludge process is about 8% with the possibility of upgrading to 20% if pure oxygen is used. With up flowing gas and liquid, the traditional three phase slurry reactor has two disadvantages, when used for biochemical fermentation or biological wastewater treatment i.e. blockage of the nozzle and low gas phase residence time. While in a jet loop reactor, when the nozzles are installed at top of the reactor, these shortcomings can be efficiently eliminated.

Jet loop reactors are widely used to ensure a homogenous suspension with low power inputs. For an optimal design of loop reactors with minimal energy consumption, the knowledge of the pressure drop in three phase mixtures is essential. This is affected strongly by the liquid circulation velocities and holdup of the different phases, essentially if particles with different densities have to be suspended simultaneously. A solid retaining grid made was fixed just below the outlet to prevent the solid particles from getting out of the reactor.

In present investigation, we have been used three phase system in modified Reversed flow jet loop bioreactor. We have been used liquid-Solid –gas system, for that as a liquid we have been used tap water, as a solid we have been used acrylic beads having diameters of 2-3 mm; & as a gas phase compressor air has been used. Average liquid circulation velocity is measured for loop circulation in annular space at different Nozzle heights for variable parameters of the modified reversed flow jet loop bioreactor. For this purpose out of various techniques; Digital image processing technique has been chosen with consideration of the merits & demerits.

2. MATERIALS AND METHODS:

2.1 Materials:

In present research work, we have been studied Two Phase as well as Three Phase system. For Two phases we used Liquid- Solid system and for three phases, we used Gas-Liquid-solid system.

We have been used following Material to carry out the experimental work.

- Compressor air as gas phase.
- Acrylic beads as a solid phase.
- Tap Water as a liquid phase.
- Polystyrene pellets as tracer particles.
- Digital camera (5 Megapixel).
- Illumination system.
- Windows movie maker operating program.

2.1.1 Physical Properties of materials:

Air:

Air (Free from moisture) is supplied from the top of the reactor through two fluid nozzles to fluidize the mixture of acrylic beads and water.

Physical properties:

- a. Density : 1.165 kg/m³
- b. Molecular weight : 28.94
- c. Thermal Conductivity at (250c, 101kpa) : 26.6×E-3W/mok

Acrylic beads:

Acrylic beads having diameter 3mm have been used as a solid material in two phase a well as three phase system. These beads are slightly denser than water

Physical properties:

- a. Density : 1100 kg/m³

Tap Water:

Tap water has been used as a liquid phase in the Two as well as Three phase System which was pumped through the two fluid nozzle from top of the reactor.

Physical properties:

- a. Density : 1000 kg/m³

Polystyrene pellets (SC 206 Polystyrene):

We have been used polystyrene pellets as tracer particles as it is having density approximately equal to water, so that by determining the velocity of the polystyrene pellets we can get the actual corresponding velocity of water within the reactor at different flow rates of the liquid as well as gas (i.e. Water & air). The polystyrene pellets were painted with different oil paints in order to determine the circulation time and velocity of the polystyrene pellets without any confusion.

Physical properties:

MFI	= 12.0
VSP	= 101° C
HDT	= 83 (Kg/cm ² 0C)
T.S.	= 470 (Kg/cm ²)
Elongation	= 2%
FM	= 32.0 (Kg/cm ² × 1000)
Specific gravity	= 1.05

From the specific gravity above mentioned, we get the idea about the density of the material is approximately equal to density of water. Thus by measuring the velocity of the tracer particle we can directly determine the value of liquid velocity.

Digital camera (5 Megapixel):

In recent years, Thanks to the continuous development of digital imaging systems and digital image processing, In present work we have been used the 5 mega pixel Digital camera made by leaders in electronics gadget producers, LG electronics. It gives us really good quality of videos and images so that we could able to determine the liquid velocities and Bubble images at different variable parameters.

Illumination System:

Really, an illumination system plays an important role in good quality picturisation. It helps to distinct the Tracer particles from the solid phase material and liquid phase at high flow rates of liquid as well as gases. It is really very difficult to identify the tracers from the system without proper illumination as turbulence is takes place at high flow rates of liquid & gas.

The contrasted background is also that much essential as illumination is. That's why we used Black background behind the reactor as well as Black, Red and Pink colored oil painted pellets particles, so that it will get visualized & could easily captured while shooting through digital camera.

We used couple of tube lights and 200 watt bulb which was covered by white paper in order to reduce the reflection due to brightness. One 60 watt bulb & series of tube lights were kept away at proper distances to get a good effect.

Windows movie maker operating program:

This is the key computer program which is bridge between the videos as well as images captured and the output data of velocities and circulation time as well as bubble size determination. It helps to count the actual time in fraction of seconds, required for the tracer through specific distance of the reactor. It also helps us to determine the circulation time for the tracer particle through reactor.

2.2 Methods: There are various types of methods which are used for study of mixing characteristics in jet loop bioreactors, such as

- Conductivity Method (Salt addition).
- PH change Method.
- Thermal Method
- Digital Image processing
- Technique/photographic method.
- Calorimetric chemical reaction method.

The choice of a suitable experimental method for mixing time measurement as well as study of mixing characteristics has been a major problem for investigators, in a spite of variety of reported methods. The major problems of our concern is that many of the methods previously applied in the literature cause a significant change in CMC solution viscosity [e.g. Conductivity method (salt addition) pH-change method, Thermal Method etc.] Periodic sampling of the liquid for off- line analysis was not feasible due to very slow rate of bubble disengagement from viscous liquids; therefore the dye addition method was dropped after some unsuccessful preliminary test.

In present investigation we have been used three phase system in modified Reversed flow jet loop bioreactor. We have been used liquid-Solid –gas system, for that as a liquid we have been used tap water, as a solid we have been used acrylic beads having diameters of 2-3 mm; & as a gas phase compressor air has been used. The measurements of local liquid circulation velocities in annular space of the reactor were done by the Digital image processing technique with help of the oil painted polystyrene pellets.

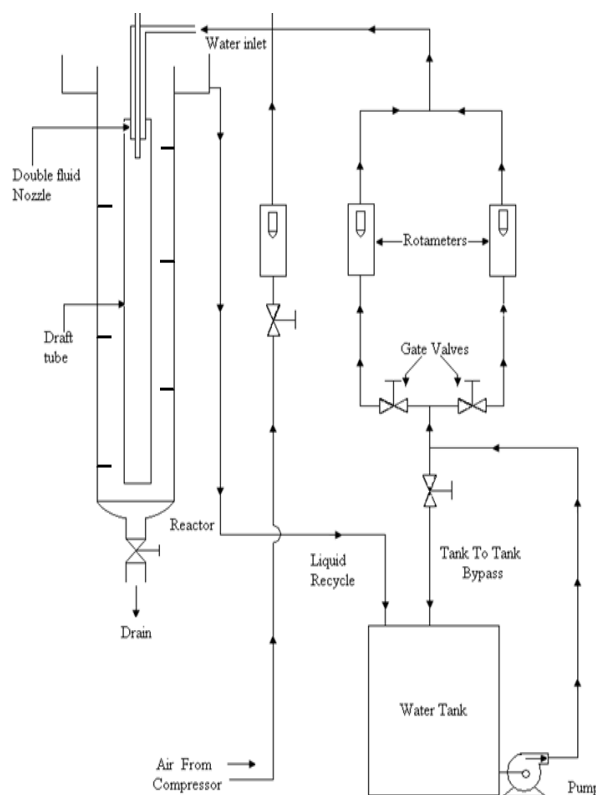
Comparatively digital image process technique may well perform a rigorous and highly detailed

assessment of experimental data and may even be adopted for the analysis of computational results conveniently expressed into image graphics as well as tabulate in to graphical form. This technique provides good visual observation without interfering with the mixing process. The different techniques for measurement of the mixing characteristics as well as behavior are already discussed in literature survey; in spite of that with consideration of all merits & demerits of all techniques we have been used Digital Image processing technique / Photographic Method among them.

A great number of researchers have chosen digital visual methods to be applied in the field of experimental fluid dynamics as well as mixing characteristics within the reactor. These kinds of techniques play a fundamental role in analysis and data acquisition for multiphase flows such as gas-solid, gas-liquid, solid-liquid flows, where the observation of inter-phase boundaries is relatively simple.

Thus Out of above mentioned methods, for the study of mixing characteristics we have chosen the Digital Image Processing Technique / photographic method.

3. EXPERIMENTAL SET UP:



Dimensions of Reversed Flow Jet Loop Reactor

Reactor Height H_r (m)	1.82
Reactor Diameter D_r (m)	0.148
Draft Tube inner diameter D_{di} (m)	0.069
Draft Tube outer diameter D_{do} (m)	0.075
Ratio Of draft tube diameter to D_o/D_i	0.506
Draft Tube Length L_{dt} (m)	1.628
Nozzle Diameter D_N (m)	0.0187
Nozzle Height H_N (m)	0.05
Nozzle Immersion Height H_{ni} (m)	0.27
Gas Flow rate Q_G (LPM)	10-50
Liquid Flow rate Q_L (LPM)	10-100

3.1 Experimental Procedure:

The liquid i.e. Water was withdrawn underneath an impact plate on which the draft tube was fixed and circulated to nozzle via flow meter (Rotameter) by means of liquid circulation pump. The gas was fed through an air tube fixed axially in the centre of two fluid nozzles. Solenoidal valves were fixed in the liquid inlet, outlet and bypass lines. The desired flow rates were regulated with the help of these valves. The top neck of reactor was tightly packed with filter cloth in such manner that it will allow passing only liquid through the filter cloth. Thus tracer particles which were painted by different colors of the oil paints will remain inside the reactor.

After proper arrangement of the illumination, the movement of the tracer particles which were already dumped into reactor was captured with the digital camera.

4. RESULT & DISCUSSION:

This Chapter enclosed with all graphical representation against different operating parameters which gives us the effect on the average tracer velocity i.e. Liquid Velocity. It gives the idea about the effect of gas flow rates, liquid flow rates, Diameter of nozzles as well as different nozzle heights. It also gives the idea about liquid velocity when it has been determined at ejector mode and when the air inlet was kept closed to atmosphere.

Effect on Liquid Velocity Profile at Nozzle height = 360,450,670 MM When Air Inlet was kept closed to the atmosphere

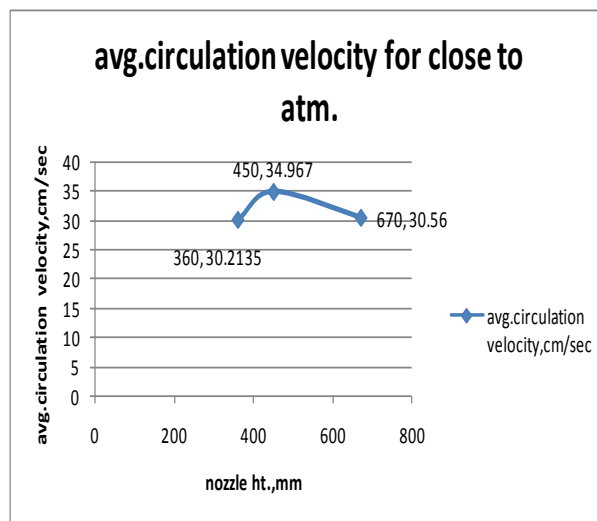


Figure 1- Average Circulation Velocity V/S Nozzle Height At Close To Atmosphere

Above graph shows that maximum tracer circulation velocity we are getting at height 450 mm and lowest tracer velocity at nozzle height 360 mm for close to atm.

Effect on Liquid Velocity Profile at Nozzle height =360,670,450 MM When Air Inlet was kept fully opened to the atmosphere

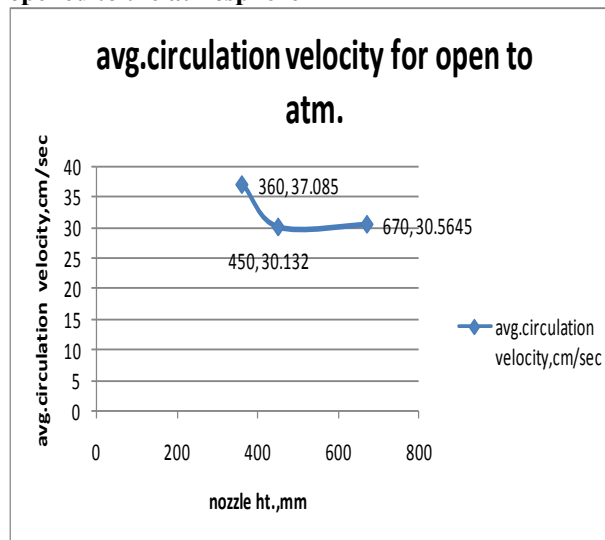


Figure 2- Above graph shows that maximum racer circulation velocity we are getting at height 360 mm and lowest tracer velocity at nozzle height 450 mm for open atm.

Effect on Liquid Velocity Profile at Nozzle height =360,670,450 MM When Air Inlet was kept fully Closed to the atmosphere

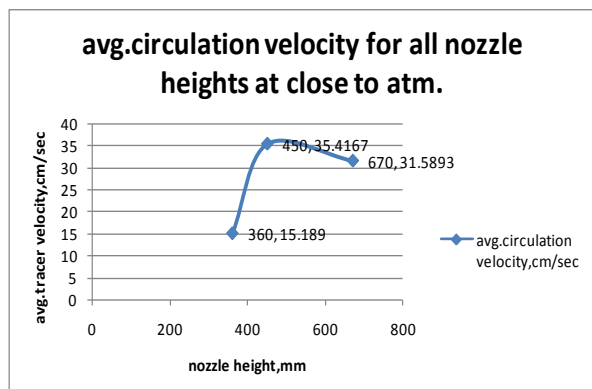


Figure 3- Average Circulation Velocity V/S Nozzle Height At Close To Atmosphere

Above graph shows that maximum tracer circulation velocity we are getting at height 450 mm and lowest tracer velocity at nozzle height 360 mm for close to atm.

CONCLUSION:-

The Effects of gas and liquid flow rates, Different Nozzle heights, Different concentration of liquid phase (Change in viscosity), different operating conditions (i.e. ejector mode, & By keeping air inlet closed) on the liquid circulation velocity have been investigated in a Three phase (liquid-solid-air) modified reversed flow jet loop bioreactor. The following conclusions are made based on the present investigation.

1. From Fig.1 we can conclude that maximum avg. Circulation velocity we getting 450 MM When Air Inlet was kept fully opened to the atmosphere.
2. From Fig.2 we may conclude that maximum avg. Circulation velocity we getting at 360 MM When Air Inlet was kept fully opened to the atmosphere
3. From Fig.2 we may conclude that maximum avg. Circulation velocity we getting at 450 MM When Air Inlet was kept fully Closed to the atmosphere
4. Liquid Circulation velocity in annular space of modified reversed jet loop reactor increases with increase in liquid flow rates and the influence of gas flow rate is more pronounced than liquid flow rate. (A. K. Sharma et. al, 1992.)

5. As Nozzle immersion height increases the liquid circulation velocity in annular space of the modified reversed flow jet loop bioreactor increases.

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