Experimental Studies on Hydrodynamic Behavior of an Air Lift Loop

[1]G.K.Pujari, [2]N.M.Rao, [3]Avssk Gupta, [4]Mallikarjuna B.B

1Department of Mechanical Engineering
VNR Vignana Jyothi Institute of Engineering Technology, Bachupally, (via) Kukatpally, Hyderabad , India
RoltaIndia Limited, Rolta Tower 'C', Rolta Technolog y Park, MIDC Marol, Andheri(E),Mumbai india
Department of mechanical engineering, JNTU College of Engineering, Hyderabad
Email: [1]gkpujari@yahoo.com, [2]nakka.rao@rolta.com, [3]avs_gupta@rediffmail.com, [4]puneetz23@gmail.com

ABSTRACT -The schematic diagram of the adiabatic ALL (Adiabatic Air-Lift Loop) indigenously designed and fabricated for the purpose of the present experiment is shown in Fig 1. It is a vertical, rectangular, open type, internal Air-Lift device. The loop consists of the following components: Two risers, one down comer, lower horizontal section and separator. All components including separator are made of transparent acrylic resin (Polyacrylic mythacralate) that allows direct visualization of the flow pattern throughout the loop.

Air flow rate was controlled by the gate valves and fine controlling of air flow rate has been achieved by simultaneous operation of inline and bypass valves. Two calibrated rotameters (range of 5-100 lpm, 2 nos) of different ranges suitable for the range of operation of the present investigation were used.

The present work is carried out to study the hydrodynamic behavior of the Air Lift Loop for different air flow rates and different levels of water in the separator tank. It is observed from the experimental results that as the airflow rate increases in the risers .The mass flow rate of water in the downcomer increased. The two phase pressure drop decreased. Further it is also found from the present study that influence of the liquid level in the two phase separator, on the two phase pressure drop and mass flow rate of water in the downcomer is negligible compare to other effects.

1. INTRODUCTION

Past few decades have seen a rapidly growing awareness for plant safety mainly driven due to the concern for the environment and increasing pressure to achieve high plant reliability and cost reduction. Engineers or Scientists are no longer concerned only regarding the efficiency of a process or a plant but also about its reliability. The possible elimination of the moving parts from working system by exploiting a suitable natural phenomenon has emerged as an obvious alternative. This explains why the applications of BICLs (Buoyancy Induced Circulation Loops) are gaining so much popularity in diverse engineering systems.

One category of circulation loops without any prime movers are operated by density difference in a fluid by bringing about changing the concentration or composition of the fluid. Air-Lift Loops (ALLs) can be cited as one successful implementation of this principle. ALLs in general, have two or three vertical limbs connected by short horizontal connections at the top and at bottom. The loop connection, also known as a separator, has a free surface open to the atmosphere, while the bottom connection is a closed passage. Air injected at the lower end of one or two of the vertical limbs (denoted as riser) rise up through it due to buoyancy. The air drags its surrounding liquid along with it during its upward motion. Air separates out in the separator but it imparts enough momentum to this liquid so that the liquid can complete the loop flowing down another vertical limb(s) (termed as down comer). These loops are extensively used in chemical and power process industries.

II. EXPERIMENTATION

The experimental facility consists of an adiabatic air lift loop associated with multiple risers with necessary instrumentation consists of a data acquisition system ,ultrasonic flow meter for the measurement of water flow rate, rotameter for the measurement of airflow rate and pressure transducers for the measurement of two phase pressure drop.

A. Adiabatic Air-Lift Loop (ALL)

The schematic diagram of the adiabatic ALL indigenously designed and fabricated for the purpose of the present experiment is shown in Fig 1. It is a vertical, rectangular, open type, internal Air-Lift device. The loop consists of the following components: Two risers, one down comer, lower horizontal section and separator. All components including separator are made of transparent acrylic resin (Polyacrylic mythacralate) that allows direct visualization of the flow pattern throughout the loop. The riser and the down comer are vertical tubes of circular cross section having identical diameters. They are connected at the bottom by a short horizontal section of same diameter. At the top, they are connected to a rectangular, gas-liquid separator, which is open to atmosphere. The details of loop geometrical dimensions are tabulated inTable 1. A gate valve at the bottom most portion of the loop serves for both filling up and draining of the liquid. Air and water are used as the test fluids. A twin cylinder air compressor has been used for the continuous air supply at constant pressure (2 bar at the delivery of the compressor) and at desired flow rate. Compressed air from the compressor passes through the rotameters in sequence before being injected in to the loop.

Air flow rate was controlled by the gate valves and fine controlling of air flow rate has been achieved by simultaneous operation of inline and bypass valves. Two calibrated rotameters (range of 5-100, 2 nos) of different ranges suitable for the range of operation of the present investigation were used.

Table 1. Details and Geometrical dimensions of the loop

Sl. No	Name of Equipment / Facility				Tube diameter (mm)	Material / Make	Qty
1	Ultrasonic Flow meter (Micro processor based)				50	Manas	01
2	Air Compressor					ELGI	01
3	Rotameters	1 No.: 0-90 lpm	2 No.: 0-90 Lpm	3 No.: 0-420 lpm	12.5	Japsin	06
4	Pentium IV Computer with Printer					Samtron	01
5	Data Acquisition Card					Dynalog India	01
6	Separator	1230	690	920		Acrylic Resin	01
7	Riser	3850			50	Acrylic Resin	02
8	Sparger			270	Outer dia 140 Inner d==dia 55s	Acrylic Resin	02

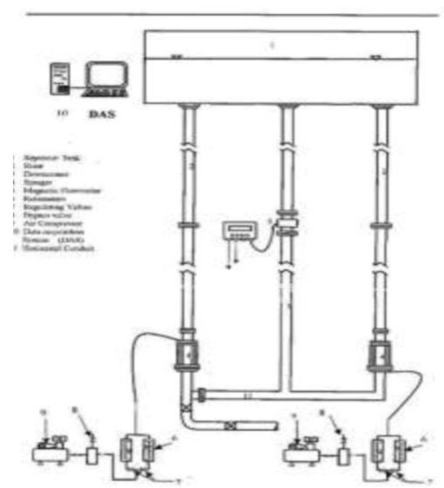

Fig 1Experimental setup of air lift loop

For supply of air into the sytem a sparger is used. Care has been taken in designing the sparger in order to provide uniform mixing of air with water and to avoid any slug formation at the inlet. The sparger is made, attaching a closed annular jacket of diameter 140 mm over the riser tube. The riser tube inside this sparger has been provided with a number of slots of 2 mm width and 270 mm height. An artificial fabric of high porosity has been wrapped over this inner tube.

The outer wall of the sparger has also eight holes, four at the top and four at the bottom. Compressed air from the rotameter goes to a distributor having eight ports. Each of these ports is connected with one hole of the sparger through flexible plastic tubing. This ensures uniform supply of air throughout the length of the sparger and entry of air in the riser tube in the form of small diameter bubble through the porous fabric. Smooth rounded riser exit and downcomer entry has been provided to minimize the exit and entry losses.

A. Experimental Procedure

For experimental study, the loop is filled with water up to a pre-determined height. Air from the compressor is supplied to the loop. Pressure, temperature and flow rate of air is monitored. Keeping the air flow rate constant the loop is allowed to run for certain time. Then signal from measuring instrument installed in the loop are recorded continuously. Visual observation of the flow phenomenon has been made and noted down. Post processing of the signal has been made after they have been recorded.

For a particular level of water, air flow rate of low value is allowed through the loop. Once all the readings for a particular air flow rate are completely taken, a higher air flow rate of air is set. Air flow rate was varied from 0.166 x 10-4 m3 /s (1 lpm) to 3.33 x 10-3 m3 /s (200 lpm). Apart from the air flow rate the water level or the total liquid inventory in the loop is also another parameter of study.

In the next series, experiments have been done with lower liquid inventory. Observations of both of these sets of operations are described below.

B. Normal Operation

Air supplied to the bottom of the air-lift loop comes out from the sparger in the form of spherical bubbles. Due to buoyancy they move up and drag the surrounding liquid phase during their rise. Passing through the riser, the twophase mixture reaches the rectangular two-phase separator at the top. The gas phase disengages from the mixture and goes to the atmosphere, while the liquid phase is pulled down through the down comer to complete the circulation. The hydrodynamics of the two-phase mixture through the riser has been studied in detail. Two sets of experiments have been conducted. In first set the first series of experiments are performed for the normal conditions for the loop. For this the height of the free surface of water in the separator is varied from 590mm to 50 mm (this measurement has been taken from the bottom of the separator) and mass flow rate for different air flow rate have been observed. In the second series of first set the behavior of loop for the different air flow rate ratios were observed. In the third series of first set the flow reversal in one of the riser have been studied by keeping air flow rate in one of the riser constant.

C. Operation under Low Liquid Inventory

In general ALL are operated with sufficient liquid storage in the two phase separator. The liquid stored in the separator reduces the momentum of the mixture. Air bubbles can no longer drag the liquid phase in the upward direction. Due to the predominant effect of buoyancy air phase separates out and goes to atmosphere, while liquid phase completes the loop passing through the downcomer. The stored volume of the liquid in the separator also dampens the flow oscillations inherent to the two phase mixture flowing through the riser. As a result, always a steady value of liquid flow rate has been recorded by the flow meter during the operation of the loop when the liquid level was sufficiently high in the separator.

However, when the liquid level in the separator is reduced below certain value the behaviour of the loop changes markedly from that of the previous case.

In the present investigation, the loop behaviour has been studied over a wide range of liquid inventory. To start with, the loop was filled with different volumes of liquid such that the free surface of the liquid in the absence of air injection covers a range of „Z‟ , where positive values of „Z‟ indicate liquid level in the separator above the top end of the riser tube (bottom of the separator tank) and negative values of „Z‟ indicate liquid level inside the riser tube, i.e. below its top end. This is shown in Figure 2. However, during operation under low liquid inventory there is substantial gas entertainment at certain operating conditions.

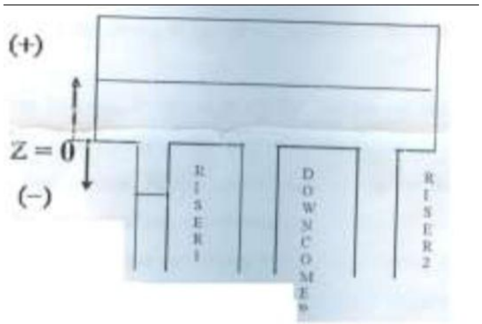

Fig.-2 Variation of the free surface of liquid

For the value of „Z‟ equal to 350 mm or above, the liquid level has no significant effect on the hydrodynamics of the loop. As the value of „Z‟ is gradually lowered from 250 mm, a unique phenomenon can be observed in the two phase separator as well as in the downcomer. The two phase mixture, which comes out of the riser with a high velocity, penetrates the free surface of the liquid level in the separator like a geyser. The outburst of the geyser is intermittent and oscillatory in nature. This induces oscillations to the whole volume of liquid present in the separator and makes the free surface wavy. Moreover, part of the air phase is dragged towards the downcomer along the free surface. This is depicted in Figure 3. Nevertheless, no carry under (entrapment of bubbles in the downcomer liquid and their downward motion) of the bubbles has been observed and the liquid circulation rate was little affected by such type of oscillations.

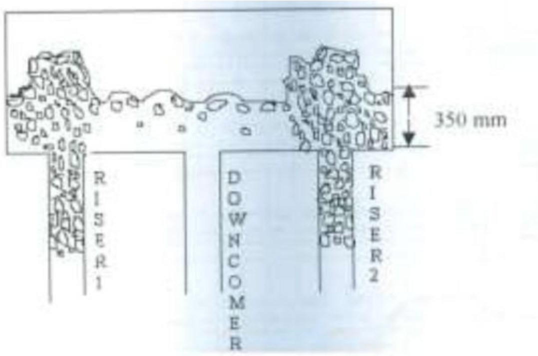

Fig-3 Geysering of two phase mixture at the riser outlet

At „Z‟ equal to 100 mm inception of another phenomenon occurs at low air flow rate. As the liquid level comes close to the entry of the downcomer an intermittent „bathtub vertex‟ forms on the free surface. At this operating condition the free surface is neither plane nor stationary. The wavy surface experiences a continuous undulatory-motion. The vortex forms when a trough of the oscillatory free surface comes close to the downcomer entry. As air core is sucked towards the downcomer, small spheroidal bubbles are continuously separated from its apex and flown down in downcomer. The phenomenon was intermittent in nature.

However, these bubbles are small and too few in number and also intermittent. With the increase of air flow rate, the liquid pull through the downcomer increases enhancing the air entrainment.

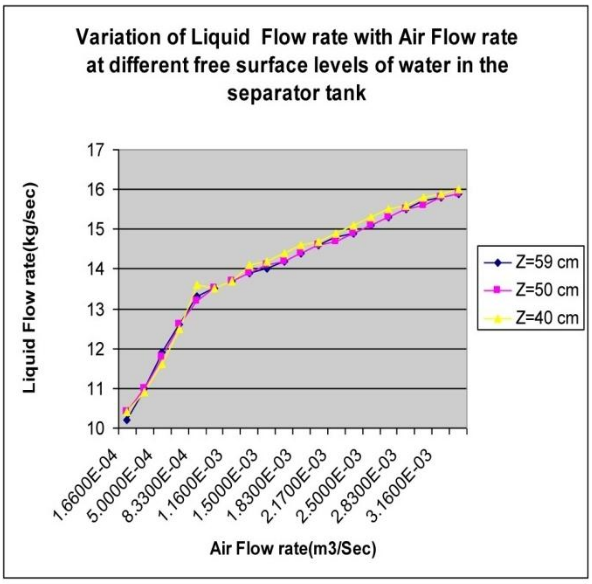

Fig-4.Liquid Flow rate

It is observed from above graph that the liquid flow rate increases with the increase in air flow rates at all levels the water in the separator tank and the variation of water level in the separator has apparently very little effect on the mass flow rate of water in the down comer in the experimental range.

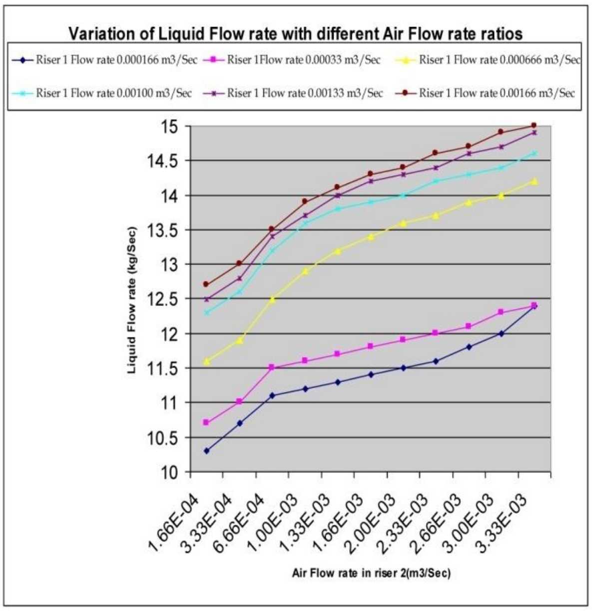

Fig-5.Air Flow rate

It is evident from the above graph that for the given flow rate of air in one riser, the increase in air flow rate in the other riser increases the mass flow rate of water in downcomer.

Summary:

The following design and analysis works are carried out

- Design and fabrication of experimental set up
- Instruments for measurement of air flow and water flow are installed
- Demonstration of two phase flow, different flow regimes, variations that occur in amount of air and water at a particular point
- Pressure drop measurement

D. Conclusions

The experiments are conducted on the adiabatic Air Lift Loop with the objective of finding the effect of air flow rate in upriser and the liquid level in the separator on the mass flow rate in the downcomer. Experiments conducted by varying air flow rate in both the uprisers and also by varying the air flow rate in one upriser by holding the air flow in the other upriser constant. In both the cases it is observed that the increase in air flow rate increases the mass flow rate of water in the downcomer.

The effect of variation of water level in the separator has very little effect on the water discharge through downcomer in the experimental range. Perhaps the effect may be appreciable with the increase in the range of free surface levels of water in the separator tank. Further investigations are being carried out to study the hydrodynamic behavior of the two phase mixture.

REFERENCES:

[1] Hestroni,G., 1982, handbook of multiphase systems, Hemisphere,Washington.

[2] Wallis,G B.,1969,One-Dimensional Two- phase flow, McGraw Hill Book company,New York.

[3] Hewitt, G.F., 1978, measurement of Two- phase Flow parameters, Academic press, London.

[4] Collier, J.G., and Hewitt, G.F., 1966, “Experimental Teechniques in Two – phase Flow,” British Chemical Engineering, II, 12, 1526- 1531.

[5] Aug.1969, Symposium on Two- phase Flow instrumentation presented at 11th National ASME/A.I.Ch.E. Heat transfer Conf. Minneapolis, Minnesota.

[6] Mishima, K.M., and Ishii, M., 1984, “ Flow regime transition criteria for upward two-phase flow in vertical tubes,” Int. J. Heat Mass Transfer, 27, 723- 737.

◈◈◈