African Journal of Science and Technology (AJST)
Science and Engineering Series Vol. 8, No. 1, pp. 56 - 62

EXPERIMENTAL INVESTIGATION OF AIR LIFT PUMP

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ABSTRACT:- *Air lift pump has been predominantly used for lifting of waste-water, aggressive fluid, transportation of solids and radioactive fluids in nuclear recycling plants and also for deep sea mining. The air lift pump performance depends on some fluid and geometric properties. Experiments were carried out by setting up a model air lift pump to unearth some of these parameters and their influence on the performance. Thereafter a Lift Dimensionless Number (LDN) and Pump Dimensionless Number (PDN) were derived to capture all the flow parameters. Using the experimental results obtained a logarithmic plot of the dimensionless numbers was obtained to established a relationship between the dimensionless numbers. It was generally observed that air lift pumps with smaller riser pipe diameters yielded higher lifts. From the experiment it was also noted that fluid with better adhesive properties (e.g. water) produced higher lifts. For all cases of injection pressures for different fluids and mixture of fluid and solid, the lift increased with increasing submergence. A logarithmic plot of LDN against PDN yielded a slope 0.22 and intercept -0.78. The study has therefore been able to generate dimensionless parameters for characterizing the lift pump.*

INTRODUCTION

The air lift pump has been used for several years in the lifting of waste water, water aggressive fluids and also for transportation of solid mixture and for radioactive fluid in nuclear recycling plants(Weber, 1982).

The method also appears well suited for deep-sea mixing provided the influence of the entrance air expansion on the degree of efficiency and on the lifting power of the air-liquid mixture is not too adverse. The usage of air lift pump for sampling Juveline Salmonds was reported by Brege et al(1990).

The great variety of applications and nearly unlimited plant dimension requires a scientific base in order to guarantee an optimal computation for each special case.As such there have been many concerted efforts to fully characterize the pump. Versluys(1931) was the first to give a general theory. There have been many theories developed since then. However some notable experimental works have equally been carried out. For instance Heywood et al(1981) reported experimental investigation of air lift pumping of shear thinning suspensions. Similarly attempt was reported by Nigel et al(1981). Wurts et al (1994) determine the individual and combined pumping capacities for floating air lift pump powered by a centrifugal blower. A physical based model was developed by Francis (1996) to determine the air flow rate required to pump a specific flow rate of water in a given well designed for in-well air stripping of volatile organic compound from an aquifer. An experimental study of air lift pump with tapered up-riser pipe was carried out by Kumar et al (2003). They reported improved performance with a tapered riser pipe. The pump performance of a small air-lift system for conveying solid particles was investigated experimentally by Hitoshi Fujimoto et al(2003). The quasi-steady state characteristics of the flows were examined for various experimental conditions The critical boundary on which the particles can be lifted is discussed in detail using a simple theoretical model

Some numerical approaches that have been attempted includes simulation of vertical conveying of solid by Weber (1982) and the use of integral model by Nenes et al (1996) . The integral model was used to simulate air lift pump for moderate deep water well by varying parameters such as pressure and void fraction. They reported close agreement with experiments.

The basis of this work is however to develop some dimensionless relations from experiments that can be used to characterise the lift pump.

EXPERIMENTAL SET UP

In order to determine the various factors governing the performance of an air-lift pump experiments were performed using a model rig as shown in Figure 1.

The rig consists of a reservoir tank made of transparent plastic material, in which stands the rise pipe (10mm – 25mm) also made of transparent plastic material. The air line is connected to the rise pipe and linked to the air compressor. The height of the liquid above the state level is referred to as the lift while the submergence is the length of the air pipe submerged below the static level.

Description of the Experiment

The reservoir tank was filled with water. The rising pipe of varying uniform diameter series (10mm – 25mm) was positioned in the reservoir tank with the air line in place.

The pipe submergence was then measured and thereafter the air was pumped into the injection point of the riser pipe. The lift of the pump (liquid height above static level) was then measured.

The experiment was repeated five times and thereafter another riser pipe of different diameter is put in place and the experiment repeated all over again.

When all the uniform rise pipes had been used, the liquid in the reservoir was change to kerosene and then gasoline and later to liquid water-solid. For each case the whole experimental runs were repeated all over again.

RESULT AND DISCUSSION

Tables 1 (a-c) showed the results obtained when the experiment was run with kerosene. The air pressure was varied from13.8 kN/m^2 to 172.4kN/m^2 and submergence

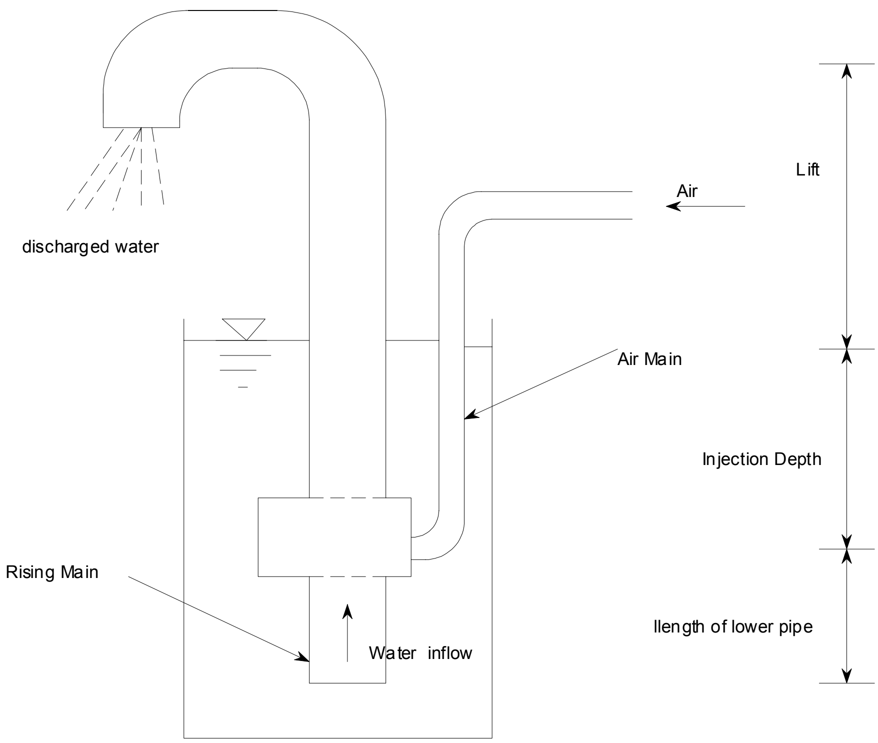

Figure 1: Schematic View of the Model Rig

Table 1: Vertical lift for different submergence and pressure at varying pipe diameters

(a) Diameter of rig = 31.5cm; pipe diameter = 25mm; height of rig = 33cm; length of pipe = 272cm

Pressure (kN/m^2)	Kerosene depth = 33cm, Submergence,25cm	Kerosene depth = 29cm, Submergence,25cm	Kerosene depth = 27cm, Submergence,25cm	Kerosene depth = 25cm, Submergence,23cm
	Height of Kerosene lifted	Height of kerosene lifted	Height of kerosene lifted	Height of kerosene lifted
13.8	70cm	62cm	50cm	32cm
20.7	83 cm	72 cm	60cm	57cm
34.5	115 cm	105 cm	100 cm	99 cm
69	143 cm	139 cm	128 cm	120 cm
86.2	172 cm	150 cm	145 cm	140 cm
172.4	260 cm	240 cm	230 cm	216 cm

(b) Diameter of rig = 27cm. Pipe diameter = 16mm; height of rig = 28.5cm; length of pipe = 283.5cm

Pressure (kN/m^2)	Kerosene depth = 28.5cm Submergence,24cm	Kerosene depth = 25cm Submergence,20cm	Kerosene depth = 22cm Submergence,18cm	Kerosene depth = 19cm Submergence,17cm
	Height of Kerosene lifted	Height of Kerosene lifted	Height of Kerosene lifted	Height of Kerosene lifted
13.8	89 cm	75 cm	67 cm	53 cm
20.7	110 cm	95 cm	85 cm	78 cm
34.5	204 cm	185 cm	173 cm	162 cm
69	250 cm	240 cm	220 cm	200 cm
86.2	270 cm	260 cm	241 cm	220 cm

(c) Diameter of Rig = 27cm. Pipe diameter = 10mm height of rig = 28.5cm, length of pipe = 180cm

Pressure (kN/m^2)	Kerosene depth = 28.5cm Submergence,24cm	Kerosene depth = 25cm Submergence,20cm	Kerosene depth = 22cm Submergence,18cm	Kerosene depth = 19cm Submergence,17cm
	Height of Kerosene lifted	Height of Kerosene lifted	Height of Kerosene lifted	Height of Kerosene lifted
13.8	131 cm	122 cm	112 cm	95 cm
20.7	153 cm	141 cm	128 cm	118 cm
34.5	172 cm	158 cm	140 cm	132 cm

from 30cm to 25cm. The graphical plot of the lift against submergence ratio (submergence/total liquid depth) for different fluids is shown in figure 2. It was observed that the pump lift increases with increasing pipe submergence ratio. This should be expected, since a greater height of the fluid will be required to restore back to equilibrium for high pipe submergences.

A plot of the pump lift (height) against pressure for different liquids is presented in Figure 3. By examining Table 1 it could be observed that the smaller riser pipe yielded higher lift than the pipe of higher dimensions. The slippage seems to be well pronounced in bigger diameter pipes.

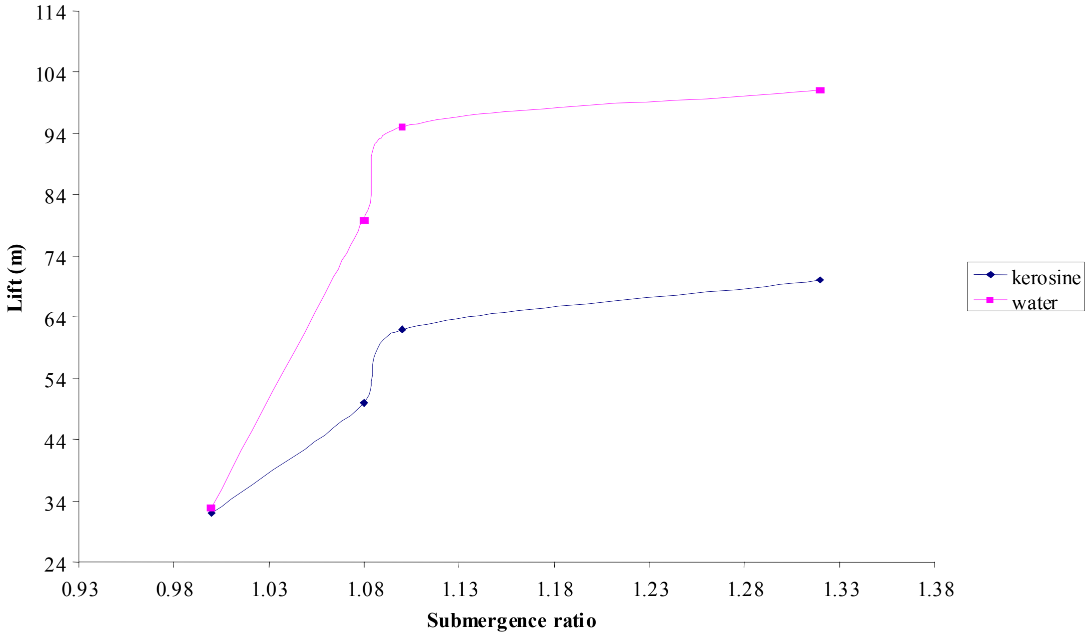

Figure 2: Plot of Lift against Submergence Ratio

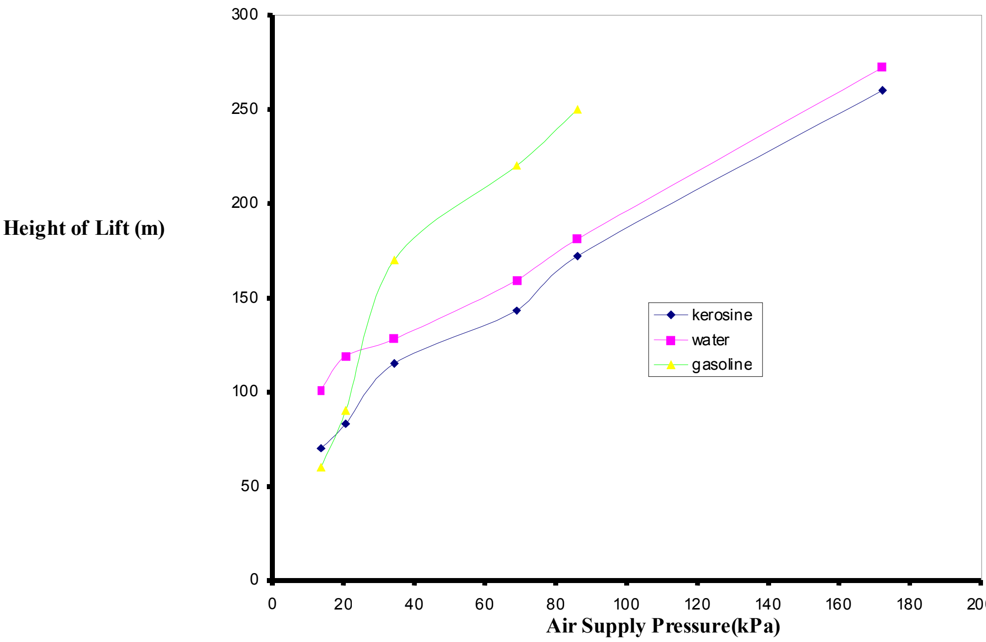

Figure 3:Plot of Lift against Supply Pressure for Different Fluids

The results obtained when a mixture of sand and water was used are presented in Table 2 while a graphical representation is shown in Figure 4. From the results it was observed that for all the air pressures and different submergence, the correspondent lift is lower comparative to the other pure liquids. The mixture is obviously denser and of considerably low cohesive properties that the other pure liquids.

Based on all the aforementioned observations, it could be deduced then that the liquid lift(L) depends on the viscosity of the liquid (μ)), its density (ρ) submergence

Table 2: Working Table for Generating Dimensionless Numbers Relations

H_s(m)	H_d(m)	Pressure, P(N/m^2	Pipe diameter, d(m)	Density(kg/m^3 at 30° C)	Viscosity(kg/ m-s at 30° C)	Lift(m)
0.33	0.3	13800	0.025	720	9.00E-04	0.7
0.33	0.3	20700	0.025	720	9.00E-04	0.83
0.33	0.3	34500	0.025	720	9.00E-04	1.15
0.33	0.3	69000	0.025	720	9.00E-04	1.43
0.33	0.3	86200	0.025	720	9.00E-04	1.72
0.285	0.24	13800	0.016	720	9.00E-04	0.89
0.285	0.24	20700	0.016	720	9.00E-04	1.1
0.285	0.24	34500	0.016	720	9.00E-04	2.04
0.285	0.24	69000	0.016	720	9.00E-04	2.5
0.285	0.24	86200	0.016	720	9.00E-04	2.7
0.285	0.24	13800	0.01	720	9.00E-04	1.31
0.285	0.24	20700	0.01	720	9.00E-04	1.53
0.285	0.24	34500	0.01	720	9.00E-04	1.72
0.33	0.3	13800	0.025	1000	4.00E-04	1.1
0.33	0.3	20700	0.025	1000	4.00E-04	1.19
0.33	0.3	34500	0.025	1000	4.00E-04	1.28
0.33	0.3	69000	0.025	1000	4.00E-04	1.59
0.33	0.3	86200	0.025	1000	4.00E-04	1.81
0.33	0.3	10300	0.025	1000	4.00E-04	1.98
0.33	0.3	17240	0.025	1000	4.00E-04	2.72
0.285	0.24	13800	0.016	1000	4.00E-04	1.1
0.285	0.24	20700	0.016	1000	4.00E-04	1.42
0.285	0.24	34500	0.016	1000	4.00E-04	2.4
0.285	0.24	69000	0.016	1000	4.00E-04	2.75
0.285	0.24	86200	0.016	1000	4.00E-04	2.83
0.285	0.24	13800	0.01	1000	4.00E-04	1.46
0.285	0.24	20700	0.01	1000	4.00E-04	1.67
0.285	0.24	34500	0.01	1000	4.00E-04	1.8
0.33	0.3	13800	0.025	760	7.60E-04	0.6
0.33	0.3	20700	0.025	760	7.60E-04	0.9
0.33	0.3	34500	0.025	760	7.60E-04	1.7
0.33	0.3	69000	0.025	760	7.60E-04	2.2
0.33	0.3	86200	0.025	760	7.60E-04	2.5
0.285	0.24	13800	0.016	760	7.60E-04	1.22
0.285	0.24	20700	0.016	760	7.60E-04	2.08
0.285	0.24	34500	0.016	760	7.60E-04	2.82
0.285	0.24	13800	0.01	760	7.60E-04	1.45
0.285	0.24	20700	0.01	760	7.60E-04	1.8

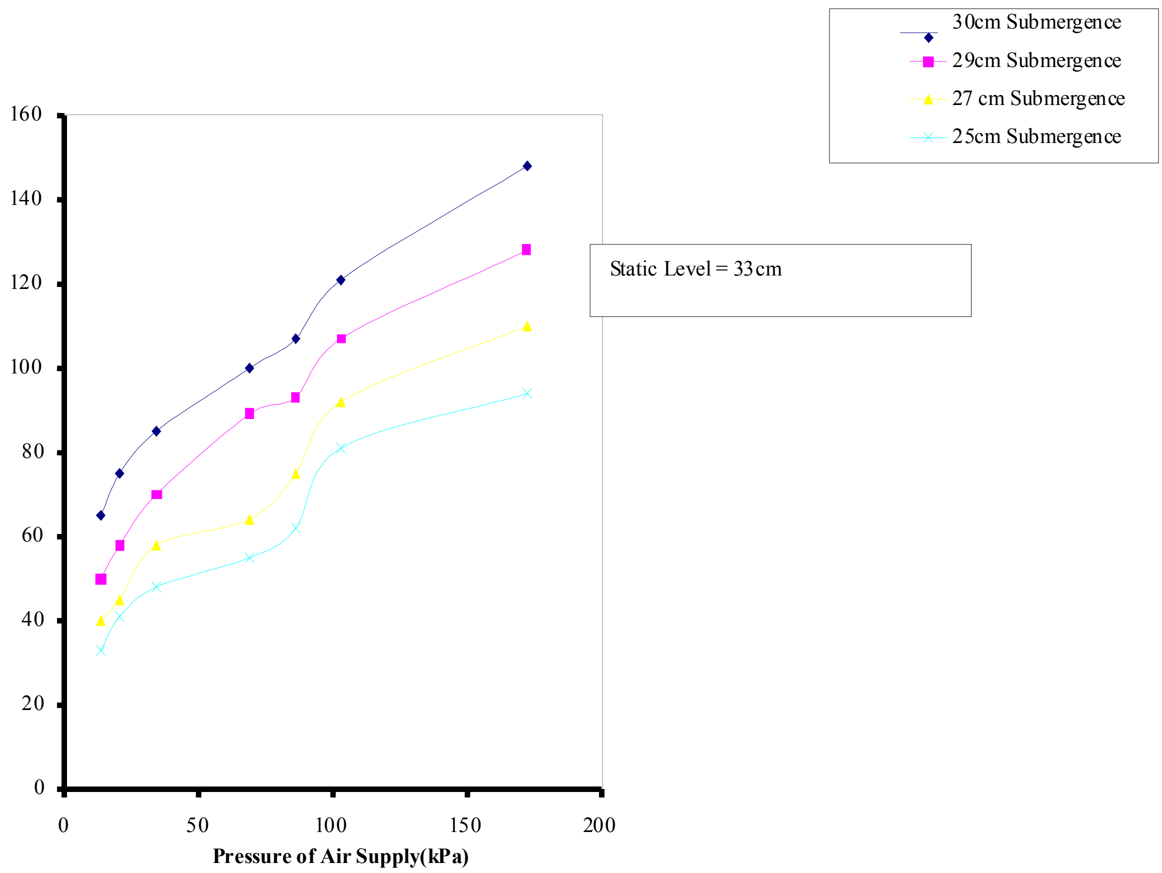

Figure 4: Plot of Water Lift against Air Supply Presure in Sand-Water Medium

depth(Hd), actual liquid static depth(Hs), diameter of pipe(d) and injection pressure(P). In other words, L= f (μ , ρ , Hd, Hs, d, P). Using Dimensional Analysis a relation was developed as LDN =f(PDN) where,

LDN = Dimensionless number = $\dfrac{L}{H_s - H_d}$

and PDN = Dimensionless number = $\dfrac{\rho P d\left(H_s - H_d\right)}{\mu^2}$

From Table 3 generated from the experiments a logarithmic plot of LDN against PDN was obtained as shown in Figure 5. The slope of the graph was obtained as 0.22 while the intercept of the graph was obtained as -0.76 (for the best line of fit). This yielded a relation LDN = 0.17PDN$^{0.22}$

Table 3: Vertical lift for mixture of sand and water at varying pressures and submergence
Diameter of rig = 31.5cm; pipe diameter = 25mm; height of rig = 33cm; length of pipe = 272cm; sand particle diameter = 2.65mm

Pressure (kN/m^2)	Water depth = 33cm, Submergence, 25cm	Water depth = 29cm, Submergence,25cm	Water depth = 27cm, Submergence, 25cm	Water depth = 25cm, Submergence,23cm
	Height of mixture lifted	Height of mixture lifted	Height of mixture lifted	Height of mixture lifted
13.8	65 cm	50 cm	40 cm	33 cm
20.7	75 cm	58 cm	45 cm	41 cm
34.5	85 cm	70 cm	58 cm	48 cm
69	100 cm	89 cm	64 cm	55 cm
86.2	107 cm	93 cm	75 cm	62 cm
103	121 cm	107 cm	92 cm	81 cm
172.4	148 cm	128 cm	110 cm	94 cm

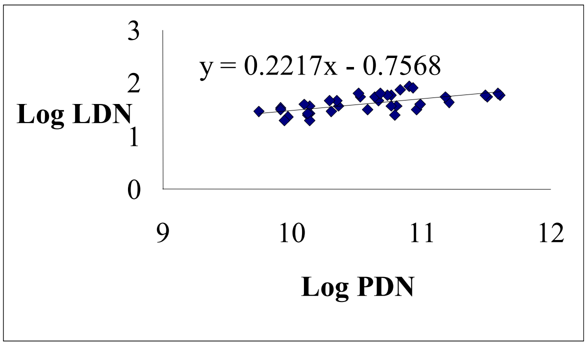

Figure 5: Logarithmic Plot of LDN against PDN

CONCLUSION

From all of the above it can be established that pipe size, configuration, submergence, air pressure and fluid type determine to a considerable extent the maximum lift produced by an air lift pump. It has also established the possibility of using dimensionless relations to characterise the pump

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