НАУЧНЫЕ ИССЛЕДОВАНИЯ
СЛОЖНЫХ МЕХАНИЧЕСКИХ СИСТЕМ

**ISSN 2227-1104. Mechanics. Scientific researches and methodical development.
Vol. 6. Gomel, 2012**

UDC 533.51

S. J. AL-MALIKY, H. A. AL-AJAWI

AlMustansiriya University, Baghdad, Iraq

ANALYSIS OF THE PERFORMANCE OF BUBBLE PUMP AND ITS PARAMETERS FOR ENVIRONMENTAL APPLICATIONS

An air lift pump system is setup to study the effect of the suction pipe diameter and submergence ratio on the liquid (water) pumping rate. The system has a lift pipe of 0.021 m diameter and 1.25 m length. Five diameters for the suction pipe (0.021–0.063 m) with a fixed length of 0.3 m are tested for the (0.2–0.5) submergence ratios. Results indicate that the higher the diameter of suction pipe the higher the pumping rate for a fixed submergence ratio. From another side, the higher the submergence ratio the higher the pumping rate for a fixed suction pipe diameter. Also, under high submergence ratios, high pumping rates are achieved by the use of lower air flow rates compared to those used with lower submergence ratios. The experimental results show good compatibility with the model suggested by Stenning and Martin for the performance of an air lift pump.

Introduction

Airlift pumping was invented by Carl Loscher at the end of the eighteenth century. Operation is based on the pumping effect achieved when air is injected into a liquid or a solid-liquid mixture. This type of pumping system has a low efficiency in comparison with other pumping methods. However, simplicity in construction and absence of moving mechanical parts are two very important advantages that make it useful in certain applications such as pumping corrosive liquids (sandy or salty waters) [1] and viscous liquids (e.g., hydrocarbons in the oil industry) [2]. Airlift pumping is also used in shaft and well drilling in which the drillings being lifted by underground water [3], undersea mining [4] and in certain bioreactors and waste-treatment installations, providing excellent aeration of the pumped fluid [5–7].

A typical airlift pump generally involves a vertical pipe of length L divided into two parts (Figure 1): *suction pipe* of length L_e between the bottom end and the air injection port (points 1 and i), and a *lift pipe* of length L_u between the air and pumping ports (points i and 2) which is partially submerged by a length L_s.

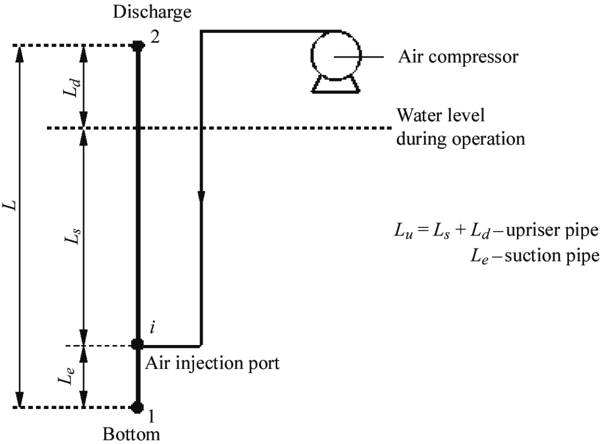


Figure 1 – A schematic for the Air lift pump

The type of flow in the suction pipe is either one-phased (liquid) or two-phased (solid-liquid) while in the lift pipe is either two-phase (air-liquid) or three-phased (air-liquid-solid). The lift pipe can be of constant or varying diameter, increasing from injection to pumping point (tapered systems). The latter are much more efficient when pumping from large depths, because it ensures slug flow along the lift. Otherwise, when a fixed diameter system is used due to gas expansion the flow changes to annular, this is characterized by poor pumping efficiency [2].

A compressed air is injected through an external or internal airline (Figure 2). At the beginning of pump operation the initial drop in water level depending on the rate of pumping is observed. There is also an additional drop in water level during pump operation but it is usually very small and, for simplicity, is omitted. Thus, two water levels

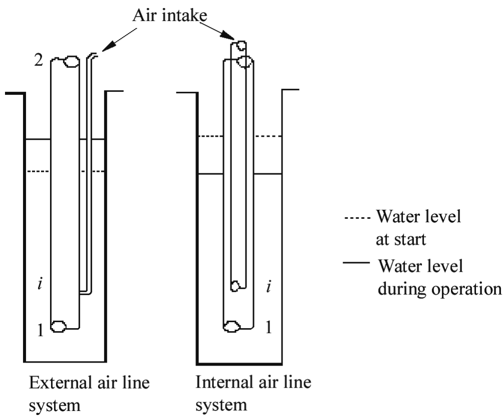


Figure 2 – Types of air injection for the air lift pump [4]

are defined, one at idling conditions and one during pump operation [1]. The first level determines the compressor hydraulic overhead, i. e., the pressure in which the compressor must initially supply air for the pump to start operating. The second level affects operation parameters (water outflow, submergence, etc.), and determines the pressure at which the pump must supply air during steady-state conditions.

Although external airline systems are more efficient, internal airline pumps are more frequently used because of their versatility and ease in assembly. As the water level inside the well fluctuates or changes, maximum efficiency can always be achieved by changing the airline length inside the lift pipe.

Pump simulation model

For this paper Stenning and Martin model [8] was used to describe the performance of the air lift pump. It describes the performance curve of the air lift pump for the non-dimensional groups, $C_{fs}\big/\sqrt{2gL}$ (refers to the pumping rate) and Q_a/Q_f (refers to the compressed air flow rate);

$$\frac{H_s}{L_p}-\frac{1}{1+\dfrac{Q_a}{S\,Q_f}}=\frac{C_{fs}}{\sqrt{2gL}}\left((K+1)+(K+2)\frac{Q_a}{Q_f}\right), \tag{1}$$

where H_s – submerged length, m; L_p – air lift pump elevation (distance between air injection point and the pumping point), m; Q_a, Q_f – air and water flow rate respectively, m^3/s; S – slip ratio; C_{fs} – velocity of water in suction pipe, m/s; g – gravitational acceleration, m/s^2; L – pipe length, m;

$$K = 4\,f\,L\,/\,D_s;$$

f – coefficient of friction (dimensionless); D_s – internal diameter of the suction pipe, m.

Slip ratio S that equals $C_a\,/\,C_f$ (velocity of air/velocity of water) is calculated using Griffiths and Wallis formula [9];

$$S=1{,}2+0{,}2\frac{Q_a}{Q_f}+\frac{0{,}35\sqrt{gD_s}}{C_{fs}}\,. \tag{2}$$

Experimental setup and procedure

The schematic in figure 1 is adopted for the purpose of this paper. The piping system consists of the following pipes:

– lift pipe: circular pipe of 0.021 m diameter and 1.25 m length;

– mixing chamber: cylindrical shape of 0.063 m diameter and 0.3 m length. It has one inlet normal to the longitudinal axis in the middle distance between the lift and suction pipes, for the compressed air (figure 2);

– suction pipe: five pipes are prepared for this paper. They are of fixed length (0.3 m) and different diameters (0.021, 0.027, 0.033, 0.048 and 0.063 m).

One is to be connected to the setup for each submergence ratio at a time. Results of such test will form the performance curves of the air lift pump for each submergence ratio.

Compressed air is to be supplied using a reciprocating air compressor of 1180 min^{-1} capacity under a pressure of 8 bar. A three phase generator of 7.5 kW power runs the compressor through a pressure switch so as to regulate the air pressure.

Results and conclusions

1 Twenty sets of tests are run for the air lift pump setup, to study the effect of the suction pipe diameter on the pumping rate. Each one of the five suction pipe diameters is tested for four submergence ratio: 0.2, 0.3, 0.4, 0.5. Results of these tests are shown in figures 3–6.

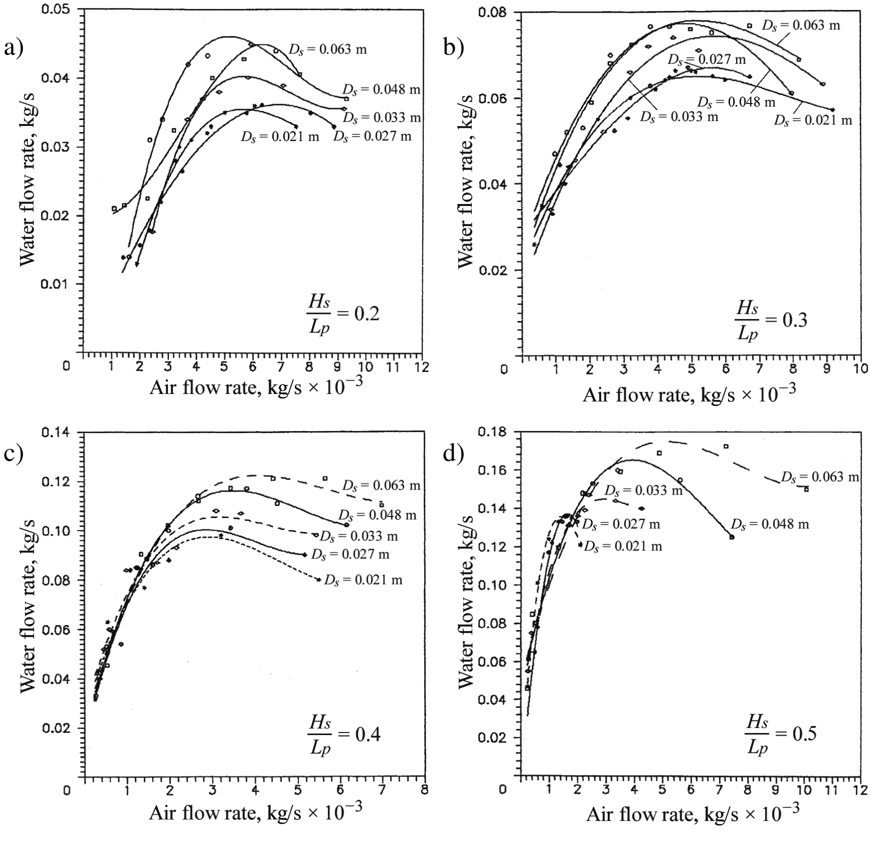


Figure 5 – Effect of suction pipe diameter on the pumping rate at submergence ratios a – 0.2, b –0.3, c – 0.4, d – 0.5

The results may be summarized as follows:

– with low air flow rates, the results indicate some fluctuations (especially for low submergence ratios), because of the unstable bubbly two phase flow effects. This situation changes as the air flow rate increases and leads to the slug flow regime.

– as the air flow rate increases, the bouncy force increases leading to an increase in the pumping rate. This situation proceeds until reaching the point of maximum pumping rate. More increase in air flow rate would result an increase in frictional losses which dominate on the bouncy force and hence reduce the pumping rate.

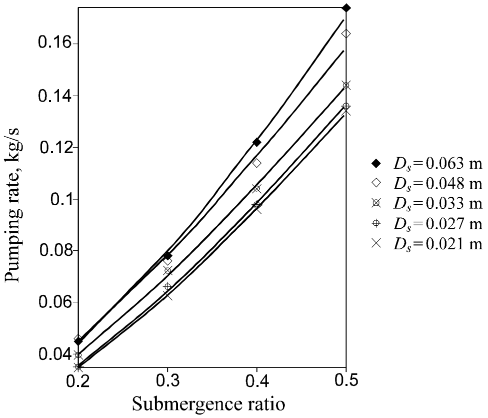


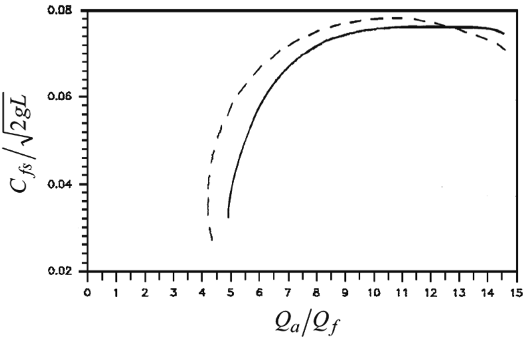
Figure 7 – The relation between pumping rate and submergence ratio for the different suction pipe diameters

– the pumping rate increases as the diameter of suction pipe increase for a fixed submergence ratio (this is illustrated in figure 7). This increase is due to the increase in the static pressure in the suction pipe and the decrease in the water velocity in the same pipe, as a result of diameter increase. This in turn leads to a reduction in the friction losses.

– from the other hand, figure 7 shows that the pumping rate increases with increasing the submergence ratio for a fixed suction pipe diameter. This is due to the reduction in pumping head from one side and the increase in the submerged length from the other side.

– under high submergence ratios, high pumping rates are achieved by the use of lower air flow rates compared with those used with lower submergence ratios. An explanation of that is, as the submergence ratio increases, the travel distance for an air bubble increases. This leads to further expansion which causes further scavenging of liquid.

2 Experimental results are compared with those gained when applying Stenning and Martin model (figure 8). The two curves in figure 8 are reasonably close, especially for high values of $C_{fs}\Big/\sqrt{2gL}$ (higher than 0,06). the differences between the two curves at $C_{fs}\Big/\sqrt{2gL}$ lower than 0,006 may be explained due to that Stenning and Martin model assumes constant values for K and S which change significantly with the change of the compressed air flow rate.



----- experimental data; —— Stenning & Martin model

Figure 8 – Comparison between the experimental data and Stenning & Martin model.

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С. Д. АЛЬ-МАЛИКИ, Х. А. АЛЬ-АДЖАВИ

АНАЛИЗ ПРОИЗВОДИТЕЛЬНОСТИ ПУЗЫРЬКОВОГО НАСОСА И ЕГО ПАРАМЕТРЫ ДЛЯ ЭКОЛОГИЧНОГО ИСПОЛЬЗОВАНИЯ

Рассмотрен подъемный воздушный насос с целью изучения влияния диаметра всасывающей трубы и коэффициента погружения на скорость откачки жидкости (во-

ды). Система имеет подъемную трубу диаметром 0,021 м и длиной 1,25 м. Выполнен эксперимент для пяти диаметров всасывающего трубопровода (0,021–0,063 м) с фиксированной длиной 0,3 м при коэффициентах погружения от 0,2 до 0,5. Результаты показывают, что чем больше диаметр всасывающей трубы, тем выше скорость откачки при фиксированном коэффициенте погружения. С другой стороны, чем выше коэффициент погружения, тем выше скорость откачки для фиксированного диаметра трубы всасывания. Кроме того, при большом коэффициенте погружения высокая скорость откачки достигается при более низком расходе воздуха по сравнению со случаем малых коэффициентов погружения. Результаты экспериментов показывают хорошее совпадение с моделью, предложенной Стеннингом и Мартином для описания работы воздушных подъемных насосов.

Получено 25.04.2012

ISSN 2227-1104. Mechanics. Scientific researches and methodical development. Vol. 6. Gomel, 2012

UDC 692.82

A. BISHA, A. LONDO

Polytechnic University of Tirana, Albania

ALUMINIUM AND GLASS CONSTRUCTION. ENERGETIC PLANNING

The features take into account the effect of various design parameters of building envelopes on the effectiveness of insulation. The ways to improve the design of window openings to provide a desired heat transfer between the areas of the building and the environment are discussed.

Sun protection for the building surfaces is the basic technique for the reduction of thermal charges inside the building in summer. Also, sun radiation is a big source of heat, which enters through the slits and leaks of the building. Proper sun protection is the main condition for all types of building lightning, no matter what light is used: natural or artificial. It contributes to keep the temperature in tolerated levels inside the building and consequently it improves comfortable thermal conditions. It significantly helps to save energy for the building cooling and to reduce electric charge in “peak time” and to reduce probability of heatstroke.

Energy conservation.

Building energy efficiency depends on the thermal performance of the constructive elements, and specifically in aluminum constructions such as cases and frames, buildings’ facades, which includes all characteristics which affect their behavior on energy consumption. Basements, frames and windowpanes play an active role in factors mentioned above. They are predominant parts of the building protective cover. Protective covers regulate the energy exchange rate between external and internal environment, so they affect the common building energy efficiency [1, 2].