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PERFORMANCE TESTS OF AN AIRLIFT PUMP EQUIPPED WITH A PERFORATED RUBBER DIAPHRAGM MIXER

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ABSTRACT

The paper presents an analysis of the tests of an airlift pump that has pumped water Q_w or a mixture of water with sand $Q_w + Q_s$. The research included a determination of performance and efficiency characteristics for an airlift pump with internal diameter of the discharge pipeline $d = 0.04$ m equipped with a PM 50 air mixer with perforated rubber diaphragm. The tests were carried out for three lifting heights of water and a mixture of water and sand H: 0.40, 0.80, 1.20 m, with a fixed length of the discharge pipeline submergence h = 0.80 m. It was found that water flow rate Q_w and the mixture of water Q_w with sand Q_s flow rate increased with the growth of the airflow rate Q_p, reaching maximum and then decreasing. Whereas with the rise of lifting height of water or the mixture of water with sand H, the water Q_w and the mixture of water Q_w with sand Q_s flow rate decreased. It has been shown that the airflow rate in this type of installation during the discharge of the water cannot be less than 5,0 $m^3 \cdot h^{-1}$ and should not exceed 16,0 $m^3 \cdot h^{-1}$. When the mixture of water with sand is discharged, airflow also cannot be less than 9.80 $m^3 \cdot h^{-1}$ and should not exceed 17.0 $m^3 \cdot h^{-1}$. The airlift pump efficiency η decreased with a rise of mixture of water with sand lifting height.

Keywords: airlift pump, air mixer, two-phase flow, three-phase flow, water flow rate, sand flow rate

INTRODUCTION

Simple structure and high reliability of airlift pumps make them suitable for various purposes. Airlift pump has no moving parts and is designed to lift liquids or mixtures of liquids and solids. This device comprises a vertical pipe partially submerged in a liquid, to which pressurised air is injected in a lower part. When injecting air into a vertical pipe, a two-phase (liquid-air) or three-phase (liquid-solid-air) mixture with less density than the density of a liquid is formed. As the mixture inside a vertical pipe becomes lighter than surrounding it liquid, it is being pushed out by air.

Airlifts were most often used for transporting liquids in both water supply and sewerage systems (Bugajski et al. 2016). Currently in Poland these devices are used for lifting sewage and sludge in small household containerised wastewater treatment plants (Kalenik 2014b, Spychała 2016) and in large ensemble of sewage treatment plants, like in sand filters (Sawicki and Pawłowska 1999, Sawicki 2004) as well as lifting deposits in rapid filters with self-regenerating bedding (Kalenik 2017) or for the restoration of drilled wells (Solecki 2010). The use costs of airlifts in water supply and sewerage systems are much lower than of centrifugal or positive displacement pumps (Polonski 2015, Rybka et al. 2016).

Airlifts are used to a much larger extent in other countries. They are applied, for example, to aerating and mixing water and removing carbon dioxide from water in fish farming industry (Barrut et al. 2012), and to mixing water in the deep lakes and its aeration by

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transporting water from the lake's bed to its surface (Fan et al. 2013).

Airlift pumps are used in petrochemistry for extracting oil from dead wells (Hanafizadeh et al. 2011) and in chemical industry for transporting corrosive, radioactive, caustic and toxic liquids (De Cachard and Delhaye 1996, Kassab et al. 2007) and for pumping boiling liquids that pass from liquid phase into gaseous phase (Khalil et al. 1999). These devices are also used for transporting suspensions in mining and lifting manganese nodules from a deep seabed (4000–6000 m) (Kassab et al. 2007). Airlift pumps can also be utilised for extracting leachates from drainage wells in landfill sites (Koda et al. 2017).

The flow in airlift pumps can be either two- (liquid-gas) or three-phase (liquid-gas-solid), which is very difficult to model mathematically, because multiphase flows depend on many factors and variables (Kalenik 2017, Kalenik 2015a, Kalenik 2015b, Kalenik 2015c, Kalenik 2014a, Kalenik and Przybylski 2011, Kalenik 2008, Wichowski and Zalewska 2015, Blazejewski and Matz 2012). Hydraulic conditions of two- and three-phase flows in airlift pumps are hardly recognised. There are attempts in providing a description of flow structures appearing in various conditions of liquid–gas or liquid–gas–solid flows and a development of so-called maps of flow structures and mathematical models for simulation their multiphase flows (Kalenik 2017, Kalenik 2015b, Kim et al. 2014, Mahrous 2014, Wahba et al. 2014, Meng et al. 2013, Mahrous 2013a, Mahrous 2013b, Mahrous 2012, Kassab et al. 2009, Yoshinaga and Sato 1996, Sawicki 2004, Sawicki and Pawłowska 1999).

Also, airlift pumps made of rectangular (Esen 2010) and curved [Fujimoto et al. 2004) pipes were tested. They show that airlift pumps with pipes curved behind a mixer have a significant drop in an efficiency of pumping solids, while the curving has no effect on an efficiency of pumping liquids alone (Mahrous 2013a). The studies reveal that airlift pumps have a lower efficiency than conventional pumps (Kassab et al. 2007, Kassab et al. 2009, Kalenik 2015b, Kalenik 2015c, Tighzert et al. 2013).

In the available literature there is little information on how to determine water flow Q_w and sand flow Q_s in an airlift pump for a particular type of mixer (Kalenik 2015b, Kalenik 2017). There is also no information on how a mixer should be designed in order to get the best performance of an airlift pump. The research conducted so far suggest that the type of mixer and the diameter of a discharge pipeline of an airlift pump affect its efficiency and hydraulic work conditions (Khalil et al. 1999, Kalenik and Przybylski 2011, Fan et al. 2013, Kalenik 2015c). The number, diameter and arrangement of holes in the mixer has a large impact on the types of two- and three-phase flow structures in an airlift pump.

To determine the efficiency of the tested airlift pump equipped with a PM50 mixer with a perforated rubber diaphragm, a modified pattern has to be applied (Pickert 1932, Nicklin 1963):

$$\eta = \left(\frac{\rho_w \rho_s g (Q_s + Q_w) \cdot (L - h)}{p_b Q_p \ln\left(\frac{p_p}{p_b}\right)} \right) 100 \qquad (1)$$

where:

- η – airlift pump efficiency, %,
- Q_w – water flow, $m^3 \cdot s^{-1}$,
- Q_s – sand flow, $m^3 \cdot s^{-1}$,
- Q_p – air flow, $m^3 \cdot s^{-1}$,
- P_p – air pressure, $N \cdot m^{-2}$,
- P_w – water density, $kg \cdot m^{-3}$,
- P_s – sand density, $kg \cdot m^{-3}$,
- P_b – barometric pressure, $N \cdot m^{-2}$,
- h – length of immersion of the discharge pipeline, m,
- L – length of the discharge pipeline to the outlet, m,
- g – gravitational acceleration, $m \cdot s^{-2}$.

This article presents an analysis of the results of efficiency tests of an airlift that pumped both water as well as sand and water. The range of tests included determining performance and efficiency rates of an airlift pump with an internal diameter of a discharge pipeline d = 0.04 m, equipped with a PM 50 type mixer with a perforated rubber diaphragm. The tests were conducted for three heights to which water and the mixture of water and sand was lifted, H: 0.40 m and 0.80 m, 1.20 m, at a fixed length of immersion of a discharge pipeline, h = 0,80 m. The tests adopted a fixed length of immersion of a discharge pipeline *h*, because in filters with self-regenerating bedding the height of water table does not change in the course of filters' operation.

DESCRIPTION OF THE TEST BENCH

The Figure 1 shows the design and function of the test bench for testing hydraulic conditions of the airlift pump. Water to the tank (3) filled with sand (4) was fed via the pipeline (1) after opening the ball valve (2). While taking measurements the tank (3) was constantly filled with water up to a height of 1 m. Excess water flowing into the tank (3) was drained away by the overflow (8), after opening the ball valve (9), to the sewerage system through floor drain (13). To drain out water from the tank (3), after opening the ball valve (15) the drainage pipeline (16) was used. Inside the tank (3), the plastic discharge pipeline (5) with the internal diameter of 0.04 m was installed at a height of 0.20 m above its bottom. The efficiency measurements for the airlift pump were taken at three heights, both for water alone and water with sand, *H*: 0.40, 0.80 and 1.20 m, measured from the level of water table in the tank (3). The mixer with perforated rubber diaphragm (10) was mounted in the discharge pipeline at a height of 0.30 m above its lower edge. Water temperature in the tank (3) was measured with the electronic thermometer (19).

The Figure 2 presents a construction of the tested PM 50 Akwatech mixer, which was equipped with the perforated rubber diaphragm (4). Air was injected into the mixer (10, see: Fig. 1) by the elastic pipeline (7) with the internal diameter 0.013 m from the compressed air tank (27), into which air was pressed by the compressor (25). The electronic air flowmeter (20), electronic manometer (21), electronic thermometer (22), poppet valve (23) and shut-off ball valve (24) were installed on the air supplying pipeline (7).

The tests were carried out with Endress+Hauser measuring devices. The measurement range of the air flowmeter (20) was between 0.0 and 30.0 $m^3 \cdot h^{-1}$, and

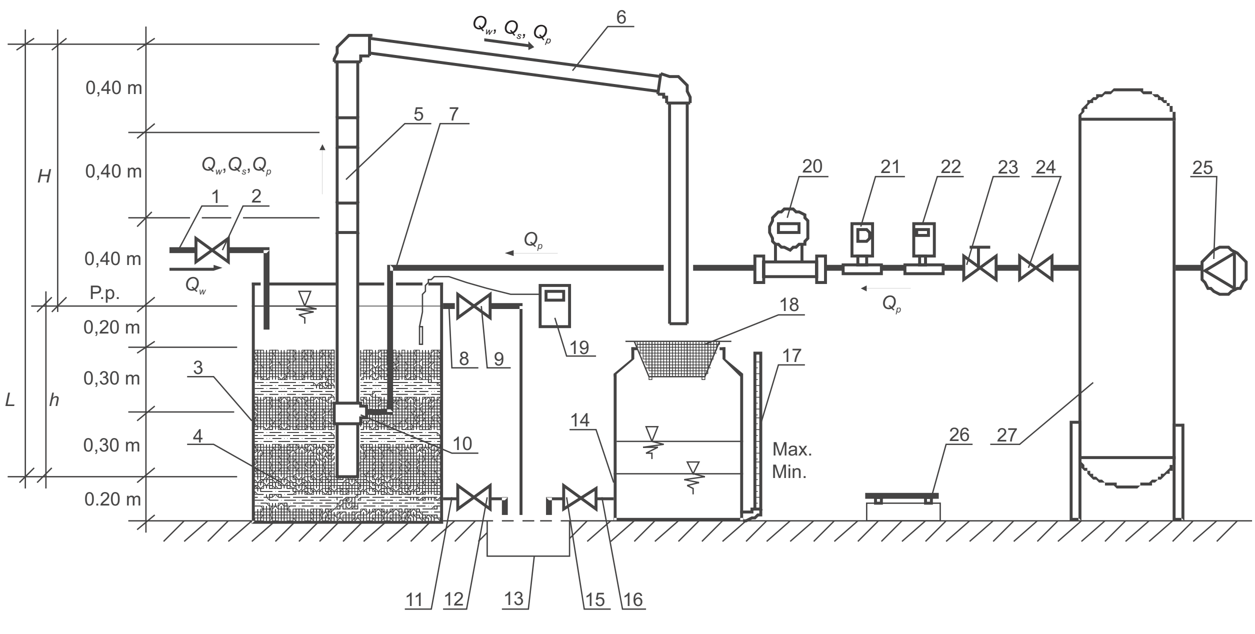

Fig. 1. Scheme of the airlift pump test bench:
1 – water supply pipeline, 2, 9, 12, 15, 24 – ball cut-off valve, 3 – tank with water and sand, 4 – sand, 5 – discharge pipe, 6 – water, sand and air discharge pipeline, 7 – air supply pipeline, 8 – overflow, 10 – mixer with perforated rubber diaphragm, 11, 16 – drainage pipeline, 13 – floor drain, 14 – measuring tank, 17 – scaled water level gauge, 18 – basket, 19, 22 – electronic thermometer, 20 – electronic air flowmeter, 21 – electronic manometer, 23 – poppet valve, 25 – compressor, 26 – scales, 27 – compressed air tank, *h* – discharge pipeline submergence length, *L* – discharge pipeline length-to-outlet, *H* – water-sand mix lifting height

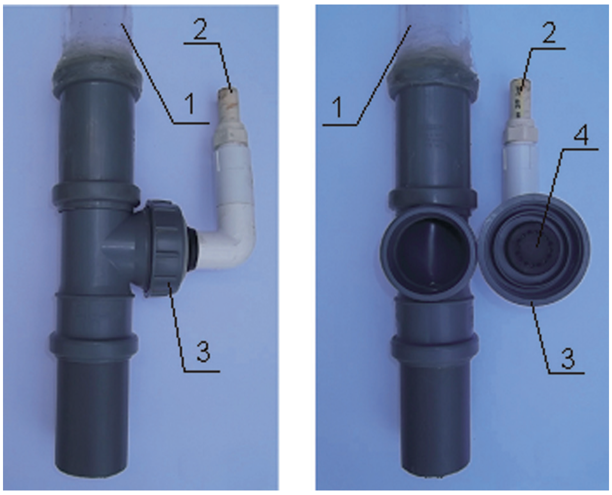

Fig. 2. Construction of the mixer with perforated rubber diaphragm – type PM 50:
1 – discharge pipeline, 2 – tip joining air supply pipeline, 3 – mixer, 4 – perforated rubber diaphragm

of the electronic manometer (20) from 0.0 to 400.0 kPa. The tests gauged water and air temperature, air pressure and barometric pressure, also the air flow rate, water volume and airlift pump's operating time and sand was weighed on the scales (26). The poppet valve (23) was used to regulate the air pressure.

The water flow rate Q_w in the airlift pump was determined by a measuring vessel method, i.e. the measuring tank (14) which was calibrated every 1 dm^3. Capacity scale of the measuring tank (14) was marked on the transparent water level gauge (17), which was set up on the side of the measuring tank. This allowed to read very accurately the volume of pumped water by the airlift per unit of time. Water itself was pumped to a given lifting height *H*, flowed down the discharge pipeline (6) with the internal diameter of 0,04 m directly to the tank (14). Then, the mixture of water and sand lifted by the airlift pump to a given height *H*, drains down the discharge pipeline (6), first into the basket (18) placed at the inlet to the tank (14). The flows of both water and mixture of water and sand in the discharge pipeline were non-pressurised (gravitational). For this purpose holes were drilled in the upper wall of the pipeline (6), through which the pumped air was discharged outside (6). While taking the measurements, sand accumulated in the basket (18) and water was drained away into the tank (14). The wet sand retained in the basket was weighted. The tests included sand with an average grain size from 0.25 to 2.0 mm, with wet weight totaling $\gamma_s = 17.4618$ kN · m^{-3}.

METHODOLOGY OF AIRLIFT PUMP TESTS

Before each series of tests on the test bench (see: Fig. 1) the barometric pressure value p_b was gauged with an electronic manometer (21). Next, on the scale of the water level gauge (17), connected to the measuring tank (14), the range of minimum level of water table in the tank (14) was marked, at which the timer was switched on, and the maximum level of water table in the tank (14), at which the timer was switched off. The marked range on the scale (17) corresponded with the water volume V_w.

The measurement of flow rate of water Q_w or water Q_w and sand Q_s mixture began with opening of the valves (2) and (9), filling the tank (3) without sand or with sand and water (4), switching on the compressor (25) and opening the valve (24) on the pipeline injecting air (7) into the mixer (10). Then, the electronic manometer (21) was set at the desired air pressure value p_p with the poppet valve (23). After setting the air pressure at a certain rate, a proportionate amount of water or water and sand, depending on the airlift pump efficiency, flowed out of the tank (3). For the measurement to be authoritative, water level in the tank (3) must remain constant. Any change of the immersion level of the mixer (10) or water level in the tank (3) has a significant impact on the efficiency of the airlift pump. The constant level of water was maintained in the tank (3) using the valve (2) located on the pipeline supplying water (1) into the tank (3). Each time the valve (2) was set in a position that balanced the outflow of water from the discharge pipeline (6) at a given air pressure value. The observation and regulation of water level in the tank (3) was related with the level of overflow (8), through which the water surplus drained away. When all these operations were executed and the conditions of the airlift pump performance stabilised, measurements were started. First, at the set air pressure value, the air flow rate Q_p was read from the electronic flowmeter (20) and air (22) and water (19) temperature – from the electronic thermometers. When water table reached the level indicated on the scale (17) in the measuring tank (14), during registering the water flow rate Q_w the timer was switched on to measure the time t of filling the tank (14) until water table on the scale (17) arrived at the maximum indicated level, at which point the timer and the poppet valve (23) that cuts off the air supply into the mixer (10) were switched off.

While taking measure of water Q_w and sand Q_s flow rate, a basket (18) was placed beneath the pipeline discharging both water and sand (6), at the inlet to the measuring tank (14) and the timer was switched to measure the time t needed to fill the tank (14) until water table on the scale (17) has reached the indicated maximum level. Then the timer and the poppet valve (23), which cuts off the air supply into the mixer (10), were switched off. Sand accumulated in the basket (18) during the tests and water was drained away into the measuring tank (14). After the time of filling the tank (14) was recorded, the sand collected in the basket (18) was weighted on the scales (26). After weighing, the sand from the basket (18) was returned to the tank (3). Then, the measuring tank (14) was emptied and the electronic manometer (21) was set to another air pressure value and the next measurement started. Measurements were made at a given air pressure p_p from 110 kPa to 200 kPa from an interval of 5 kPa. The water flow rate Q_w was calculated by dividing the volume of water V_w in the measuring tank (14) by the time of its filling t, and the sand flow rate Q_s was calculated dividing the weight of sand accumulated C_s in the basket (18) by the time of its filling t and the sand density ρ_s. The tests consisted of five series each for every set air pressure value p_p and all three heights to which water and the mixture of water and sand H were lifted: 0.40, 0.80, 1.20 m, measured in relation to the position of water table in the tank (3).

DISCUSSION OF THE TESTS RESULTS

The Figure 3 shows a distribution of the air flow rate Q_p in the airlift pump with the PM 50 type mixer, depending on the set air pressure p_p and the lifting height of water as well as the mixture of water and sand H. Analysing the obtained results it can be said that the air flow rate in the airlift pump raised along with the increase of air pressure. While the increase of both water as well as the mixture of water and sand lifting height, with constant immersion of the mixer and fixed air pressure values, had little effect on the drop in the air flow. Due to a large amount of air the air flow rate at its given pressure were comparable, regardless of the lifting height of both water and the mixture of water and sand.

However, the mixture of water and sand entailed higher air flow rate than water alone. This was caused by higher hydraulic resistances of the flow of the mixture. Because air is compressible, a larger amount was needed to overcome a higher hydraulic resistance and lift the mixture of sand and water.

The Figure 4 presents the results of measurements of the water flow rate Q_w in relation to the air flow rate Q_p and the lifting height of water H. It was found that the water flow rate Q_w in the airlift pump

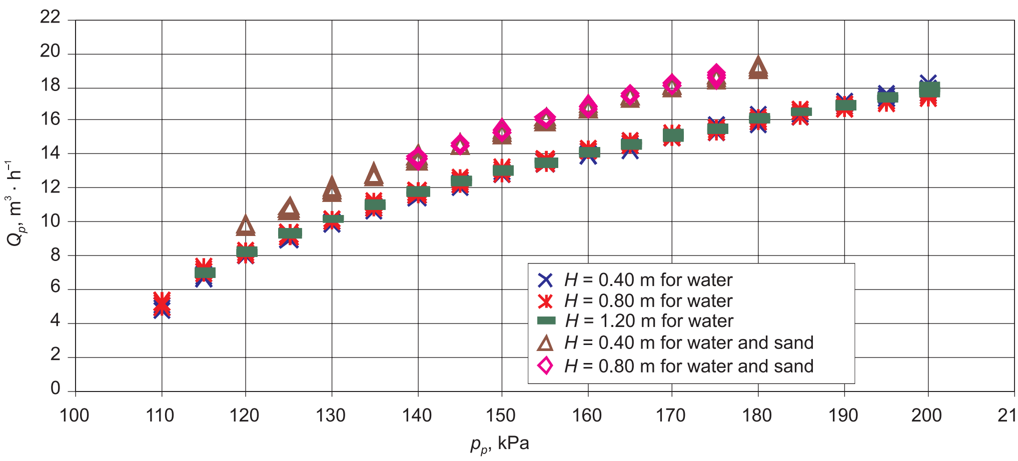

Fig. 3. Air flow rate Q_p in the air lift pump vs. air pressure p_p and water-sand mix lifting height H

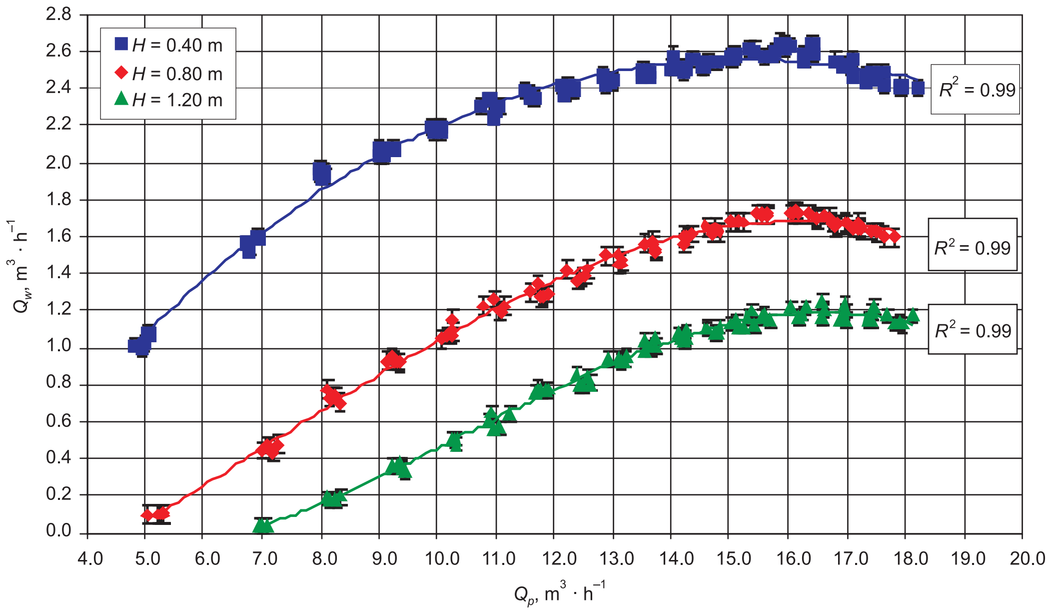

Fig. 4. Water flow rate Q_w vs. air flow rate Q_p

with a PM50 mixer decreased with simultaneous increase of water lifting H, and raised along with the increase of both air flow rate Q_p and air pressure p_p. The adequate minimum air flow rate $Q_{p\min}$ and minimum air pressure $p_{p\min}$ must be provided in order to keep water flowing from the airlift pump at required heights. With the increase in lifting height of water H, the minimum required rate of air flow $Q_{p\min}$ in the discharge pipeline increased, too. The tested airlift pump design (see: Fig. 1 and 2) for lifting height $H = 0.40$ m requires the average minimum air flow rate $Q_{p\min} = 4.97$ m$^3 \cdot$ h^{-1}, which corresponds to the pressure $p_{p\min} = 110$ kPa, while for lifting height $H = 0.80$ m: $Q_{q\min} = 5.24$ m$^3 \cdot$ h^{-1} and $p_{p\min} = 110$ kPa, and for $H = 1.20$ m: $Q_{q\min} = 7.01$ m$^3 \cdot$ h^{-1} and $p_{p\min} = 115$ kPa. In the tested airlift pump with the PM 50 mixer for the heights of lifting water set at H: 0.40, 0.80 and 1.20 m, if the average air flow rate exceeded the $Q_p = 16.10$ m$^3 \cdot$ h^{-1}, which corresponded to the set air pressure $p_p = 180$ kPa, the water flow rate Q_w in the airlift pump still did not grow, but only decreased. It means that for the tested airlift pump with the PM50 type mixer (see: Fig. 2), in which the submergence length of the discharge pipeline h was 0.80 m (see: Fig. 1), for pumping water alone maximum required air flow rate Q_p should not exceed 16 m$^3 \cdot$ h^{-1}.

In Figure 4, trend lines, standard error bars and determination coefficients of R^2 trial were also included for the Q_w value. The functional dependency between the water flow rate and the air flow rate had a non-linear tendency, and the trend type (regression) was a third-degree polynomial in the range of Q_w values recorded in the tests. The trend lines for Q_w values were parallel to the increase of water lifting height H. The values of the R^2 coefficient were above 0.99, which indicates that the water flow rate in the airlift pump in at least 99% depended mainly on the air flow rate, and thus on the set air pressure and water lifting height, with only 1% on other factors like water and air density, roughness of the discharge pipeline or gravitational acceleration.

The Figure 5 presents the results of measurements of flow rate of water Q_w and sand Q_s, depending on the air flow rate Q_p and the lifting height of water and sand mixture H. In the tested design of the airlift pump with the PM 50 mixer for the lifting height of the mixture of water and sand $H = 0.40$ m, the water flow rates were lower than the sand flow rates, and for the lifting height of the mixture of water and sand $H = 0.80$ m, reverse relations were obtained. Unfortunately, the test airlift (see: Fig. 1 and 2) was not able to raise the mixture of water and sand to the height $H = 1.20$ m. The

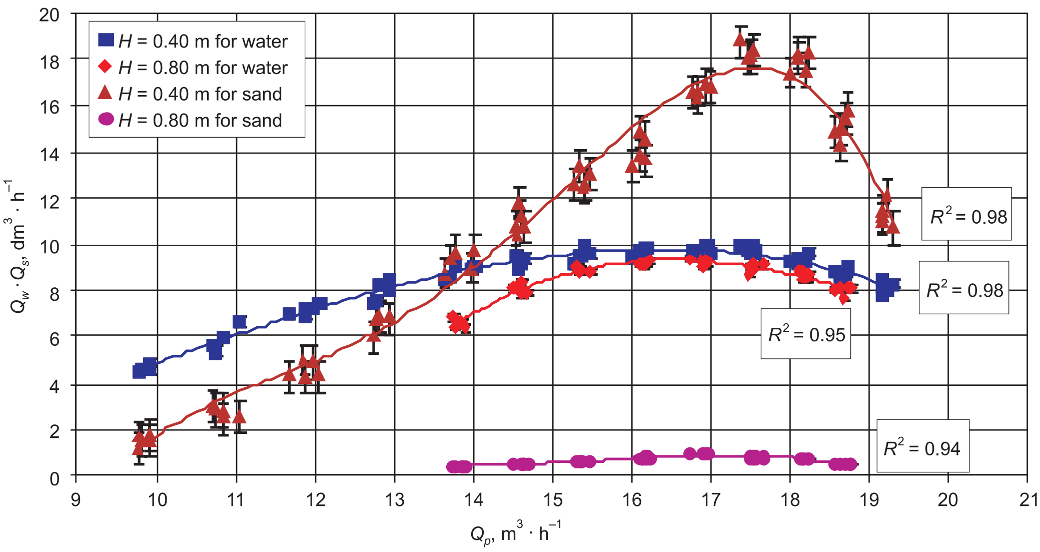

Fig. 5. Water flow rate Q_w and sand flow rate Q_s vs. air flow rate Q_p

values of water and sand flow rates decreased with the increase in lift of the water and sand mixture, and grew with the increase of the air flow rate reaching the maximum, and then decreased again.

The sand grain of size 0.25–2.0 mm was to be able flow out of the airlift pump at the required lifting height, because an adequate minimum air flow rate has been provided. The lifting height of the water and sand mixture increases, when the required minimum air flow rate and thus minimum set air pressure in the discharge pipeline grew, too. To raise the mixture of water and sand to the height of H = 0.40 m with the tested airlift pump, it is necessary to set the minimum average air flow rate at $Q_{q\min}$ = 9.85 m^3 · h^{-1}, with corresponding air pressure of $p_{p\min}$ = 120 kPa. However, for the lifting height of water and sand mixture H = 0.80 m, these values were respectively $Q_{p\min}$ = 13.82 m^3 · h^{-1} and $p_{p\min}$ = 120 kPa.

For the lifting height of the mixture of water and sand H = 0.40 m, when the average air flow rate exceeded 17.48 m^3 · h^{-1}, which corresponded to the air pressure set at 165 kPa, the values of water and sand flow rate did not increase further, but decreased. Whereas for the lifting height of the mixture of water and sand H = 0.80 m, this occurred when the average air flow rate passed Q_p = 16.87 m^3 · h^{-1}, with corresponding air pressure of p_p = 160 kPa. Both for two-phase (water-air) and for three-phase flow (water-sand-air) this is described in scientific literature (Kassab et al. 2009, Hanafizadeh et al. 2011, Kalenik and Przybylski 2011, Meng et al. 2013, Kalenik 2015b, Kalenik 2015c, Kalenik 2017) and means that in the case of studied airlift pump design (fig.1 and 2) for the flow of water and sand mixture the maximum of required air flow rate should not exceed 17 m^3 · h^{-1}.

In Figure 5, trend lines, standard error bars and coefficients of determination from the trial R^2 were included for the Q_w and Q_s values. The functional dependency between the water and sand flow rate and the air flow rate also had a non-linear tendency; a trend type (regression) for the Q_s value was a fourth-degree polynomial, while for the Q_w value was a third-degree polynomial, within the range of Q_s and Q_w values obtained in the tests. The trend lines for Q_s and Q_w values with an increase in the water lifting height H were not parallel to each other. The R^2 coefficient values were above 0.94, which indicates that the sand and water flow rate in the airlift pump as well as in at least 94% depended mainly on the air flow rate, and thus on the set air pressure and water lifting height, with only 6% on the rest of the factors like the density of sand or water and air, the roughness of the discharge pipeline, gravitational acceleration.

The efficiency of the tested airlift pump (see: Fig. 1 and 2) was determined by using the results of measurements of the water Q_w and sand Q_s mixture flow rate with the formula (1). By analyzing the results (see: Fig. 6), it can be concluded that the efficiency η of the airlift pump, for the lifting heights of the mixture of water and sand H: 0.40 and 0.80 m, with an increase in air flow rate Q_p and thus also in air pressure p_p, initially slowly raised, reaching the maximum value, and then dropped. In the case of the lifting height of water and sand mixture $H = 0.40$ m, the highest efficiency of the tested airlift pump was reached with the average air flow rate $Q_p = 13.82\ m^3 \cdot h^{-1}$ for which the set air pressure was $p_p = 140$ kPa, and which amounted to η = 27%. Whereas for the lifting height of the mixture of water and sand $H = 0.80$ m, these values were respectively $Q_p = 14.60\ m^3 \cdot h^{-1}$, $p_p = 145$ kPa and η = 22%. For the air flow rate over 15 $m^3 \cdot h^{-1}$, for the lifting heights of the mixture of water and sand H, η efficiency decreased. This was due to the fact that when the air flow rate Q_p increased, in the discharge pipeline of the airlift pump more air bubbles formed, occupying a larger space in the cross-section area of the discharge pipeline, and then the space that could consist of the mixture of water and sand was reduced. However, the increase of the air flow rate in the discharge pipeline resulted in the increase of the flow of the mixture water and sand, which, in turn, caused the increase of friction and decrease of the efficiency of the tested airlift pump. Efficiency η of the air lift pump also decreased when the lifting height of the water and sand mixture H rose, as the linear hydraulic resistance grew along the length of the discharge pipeline and the water and sand mixture's flow rate decreased.

SUMMARY

In the tested airlift pump with the PM 50 type mixer the air flow rate Q_p grew with the increase of the air pressure p_p. Also, the water flow rate Q_w and the mixture of water Q_w and sand Q_s grew with the increase in the air flow rate Q_p reaching a maximum, and then dropping. However, with the increase in the water lifting height or the water and sand mixture lifting height H, the water flow rate Q_w and the mixture of water Q_w and sand Q_s decreased.

In the tested airlift pump design with the internal diameter of the discharge pipeline $d = 0.04$ with the PM 50 mixer and a constant immersion length of the discharge pipeline $h = 0.80$, the water as well as the mixture of water and sand flow rate grew with the increase in the air flow rate and amounted to, respectively: for water the average from 5.0 $m^3 \cdot h^{-1}$ to 16.0 $m^3 \cdot h^{-1}$, for the mixture of water and sand from 9.80 $m^3 \cdot h^{-1}$ to 17.0 $m^3 \cdot h^{-1}$. However, in the case of higher air flow rates, the water flow rate and the mixture of water and sand decreased. Therefore, it is recommended that the air flow rate in this type of device, when pumping water is not below 5.0 $m^3 \cdot h^{-1}$ and does not exceed 16.0 $m^3 \cdot h^{-1}$. When pumping the mixture of water and sand it is also recommended that the rate is not smaller than 9.80 $m^3 \cdot h^{-1}$ and does not exceed 17.0 $m^3 \cdot h^{-1}$.

The efficiency η of the tested airlift pump decreased, when the lifting height of the mixture of water and sand was increased.

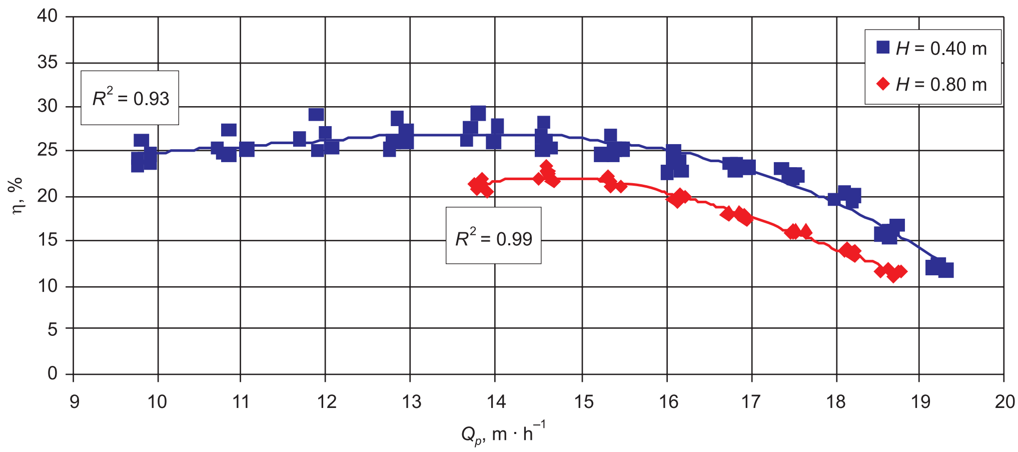

Fig. 6. Efficiency η of the air lift pump depending on the air flow rate Q_p – for water and sand

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BADANIA WYDAJNOŚCI POWIETRZNEGO PODNOŚNIKA WYPOSAŻONEGO W MIESZACZ Z PERFOROWANĄ GUMOWĄ MEMBRANĄ

ABSTRAKT

W artykule przedstawiono analizę wyników badań laboratoryjnych powietrznego podnośnika, który tłoczył wodę z wydajnością Q_w lub mieszaninę wody i piasku $Q_w + Q_s$. Zakres badań obejmował wyznaczenie charakterystyk wydajności i sprawności pracy powietrznego podnośnika o średnicy wewnętrznej rurociągu tłocznego $d = 0,04$ m, wyposażonego w mieszacz typu PM 50 z perforowaną gumową membraną. Badania wykonano dla trzech wysokości podnoszenia wody oraz mieszaniny wody i piasku H: 0,40, 0,80, 1,20 m, przy stałej długość zanurzenia rurociągu tłocznego h = 0,80 m. Stwierdzono, że natężenie przepływu wody Q_w oraz mieszaniny wody Q_w i piasku Q_s rosło wraz ze wzrostem natężenia przepływu powietrza Q_p, osiągając maksimum, a następnie malało. Natomiast wraz ze wzrostem wysokości podnoszenia wody lub mieszaniny wody i piasku H, natężenie przepływu wody Q_w, jak również mieszaniny wody Q_w i piasku Q_s malało. Wykazano, że natężenie przepływu powietrza w tego typu urządzeniu podczas tłoczenia wody nie może być mniejsze niż 5,0 $m^3 \cdot h^{-1}$ i nie powinno przekraczać 16,0 $m^3 \cdot h^{-1}$. Podczas tłoczenia mieszaniny wody Q_w i piasku Q_s również nie może być mniejsze niż 9,80 $m^3 \cdot h^{-1}$ i nie powinno przekraczać 17,0 $m^3 \cdot h^{-1}$. Sprawność η badanego powietrznego podnośnika malała wraz ze wzrostem wysokości podnoszenia mieszaniny wody i piasku.

Słowa kluczowe: powietrzny podnośnik, mieszacz, przepływ dwufazowy, przepływ trójfazowy, natężenie przepływu wody, natężenie przepływu piasku