AIRLIFT PUMPS, AQUACULTURE, CFD, FLOATING RACEWAYS

HELPING A LARGE SCALE FISH FLOATING RACEWAY IN ONTARIO

By Dr. Sherif Abdou and Dr. Wael H. Ahmed

INTRODUCTION

An airlift pump is a device that utilizes the principles of buoyancy of pressurized injected air at the base of a submerged riser tube to act as pneumatic pistons to lift the submerged water to the top of the riser tube.

These pumps have been used in the oil and gas industries, as well as in the wastewater industry.

The increase in knowledge and understanding of two-phase flow have made it possible to study and analyze the various parameters that affect the performance of an airlift pump.

This has led to improved pump designs that maximize the efficiency and performance potential.

Using airlift pumps in industries where a supply of pressurized air is readily available, such as in the aquaculture industry, can reduce the complexity of the system while enhancing its performance. The operation of an airlift pump involves injecting compressed gas at a certain depth below the fluid level in a partially or fully submerged pipe.

This creates an interaction between the gas and the liquid, thus creating a two-phase flow system. Since most gases are far less dense than liquids, the gas starts to rise in the up riser pipe. The forces acting on the gas-liquid mixture are buoyancy, which acts as the lifting force, as well as inertia and gravity, which act as the opposing forces. When the lifting forces are large enough, the liquid rises along the pipe to the level at which the acting forces are equal.

The performance of an airlift pump is tied to the submergence level of the airlift system, the up riser pipe diameter, and the two-phase flow pattern experienced in the pipe. The submergence level is quantified through a parameter called the submergence ratio. This ratio represents the amount of static lift in comparison to the total lift of the airlift system. The submergence ratio is the most significant parameter affecting the operation of airlift pump systems.

In this study, FloNergia FloMov™ airlift pumps are used. A 1-inch FloNergia FloMov™ pump was used in a laboratory


Izumi Raceway

system at the University of Guelph to determine the performance curves of the FloNergia FloMov™ airlift pump system and to perform CFD methodology validation. A set of four 4-inch FloNergia FloMov™ pumps were used for the fieldwork.

This fieldwork was carried out at Izumi Aquaculture in Aberfoyle, Ontario, Canada to investigate the operation of such pumps in a floating raceway system designed for depleted quarries using FloNergia FloMov™ airlift pumps measuring velocity profiles across the raceway.

The field study results were then used to verify the results of the CFD model for a raceway simulation.

REUSING DEPLETED QUARRIES AS FISH FARMS

As armor stone and limestone quarries in Ontario, Canada are depleted of their mineral wealth, they create a challenging problem of site rehabilitation for the property owner. Izumi Aquaculture has developed a viable alternative by turning these facilities into steelhead salmon fish farms managed using floating raceway technology.

WHY A FLOATING RACEWAY?

Floating raceways offer a new opportunity to develop aquaculture production capacity. Because raceways provide solid-walled containment of fish, the ability to manage fish and fish wastes is comparable to traditional land-based

Izumi FloMov Pumps Installed

SUMMARY

Currently, very few aquaculture operations are employing airlift pump technology for water recirculation, aeration, and waste removal. This is likely due to the poor design and lower efficiency of traditional airlift design, the limited amount of research effort that has been invested in improving performance capabilities of airlift pumps, and the general lack of awareness of the industry about the inherent advantages of airlift systems. A new efficient airlift pump is hydrodynamically designed by incorporating the Volume of Fluid (VOF) multiphase model along with Computational Fluid Dynamics (CFD) tools.

The pump is designed to offer a substantial reduction in total energy usage as well as an improved quality of the culture products in order to make it attractive to the aquaculture industry. In this case study, both numerical and experimental investigations were carried out for airlift systems operating under two different submergence ratios of 50% and 90% in a lab setting using 2.54 cm diameter pumps.

Additionally, the performance of large-scale pumps of 10.16 cm diameters were tested in an aquaculture raceway to determine its effect on the operation. The numerical results were found to be in agreement with the experiments within ±20% which is considered very reasonable for multiphase flow analysis. The study is in the development of an exceptional tool for modelling the airlift pump performance, and for the successful integration of these pumps into aquaculture systems.

farms and facilitates similarly high rates of feed conversion. Floating raceway technology provides control over water quality, temperature modulation, removal of settle-able solids (uneaten fish feed and fish waste), dissolved oxygen levels, and water velocity. Since the raceways sit in water, pumping and circulating water through the raceways is extremely energy efficient with overall capital and operating costs that are comparable to the low cost of production in net pens. When floating raceways are located within confined ponds with no surface discharge or outflow there is no chance of fish escaping to the broader environment or for any nutrient discharge to nearby receiving waters.

INSTALLATION

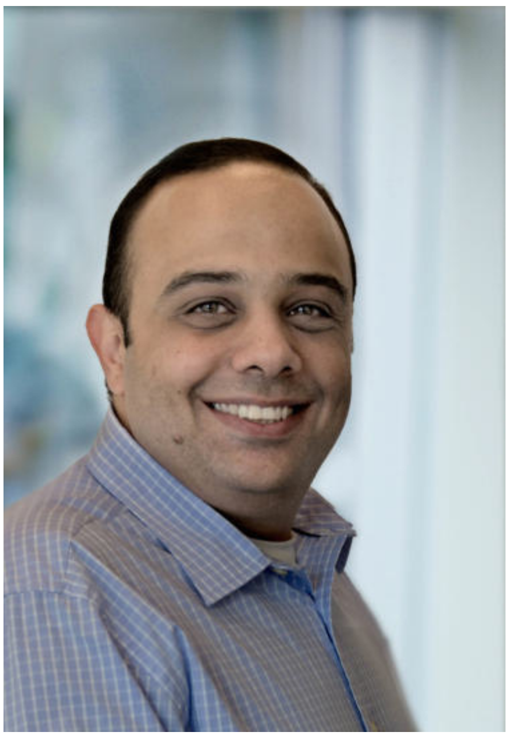
An airlift pump system consisting of four 4-inch FloMov pumps supplied by FloNergia was installed at an aquaculture facility in Southern Ontario to study the effects of pumping system on the flow and operation through the raceway. The raceway system is built on a floating dock in a closed lake creating a recirculating system. Frames were built to fit on one end of each raceway and the airlift pump system was attached to it. The pumps lift water from a depth of 1.78m into the raceway and the water then exits the raceway through an opening at the opposite end. The FloNergia FloMov™ airlift pump units have a nominal inner diameter equivalent to a 4 inch (1.016×10−1m) PVC pipe. The air supply was provided by regenerative air blowers that were present on site.

STUDY RESULTS

Numerical simulations were performed on the FloNergia FloMov™ airlift pump system operating under two submergence ratios: 50% and 90%, as well as on the airlift pump systems installed in the aquaculture raceway. The numerical modelling of the airlift pump performance was found to be within ±20% RMS of the experimental values, while also providing better predictions over an analytical model. Other two-phase flow phenomena were also examined to provide deeper fluid analysis. The flow of an airlift pump system integrated raceway was also studied numerically to understand the effectiveness of the airlift pumps performance on the raceway. This simulation analyzed the velocity field across the raceway and compared them to experimental velocity measurements. It was found that the numerical velocity field is agreeable with the experimental measurements and that the operational velocity values were reached.

These results showed that the use of computational fluid dynamics could be used to study the performance of FloNergia FloMov™ airlift pump systems and allow them to be included in the design stages of a project. This would permit the integration of the FloNergia FloMov™ pumps into aquaculture systems by obtaining an accurate prediction of the operating conditions.

About the Authors



Dr. Sherif Abdou *is a budding entrepreneur with a mechanical engineering background and a passion for interdisciplinary sciences. Sherif completed his Ph.D. degree in mechanical engineering from McMaster University in 2014 where he developed a novel micro pump for microfluidic and lab-on-a-chip applications. Since then, Sherif has been involved with a startup company in the automotive field before co-founding his own company in 2017 to commercialize an innovative pumping/aeration technology developed at the University of Guelph. In 2019, he launched a new company to help other businesses adopt and utilize numerical modelling in their product design and development process.*

Dr. Wael Ahmed *is a full professor at the University of Guelph. His expertise in the area of experimental multiphase flow analysis of water, food, and energy systems. Wael received his Ph.D. in Mechanical Engineering from McMaster University in 2005. He has over 25 years of academic and industrial experience. He designed efficient airlift pumps for many industrial applications including food, oil & gas, and nuclear energy.*

FloNergia Inc. *specializes in the supply of airlift pumping systems for commercial and industrial applications involving the use of air to efficiently move fluids. FloNergia's FloMov™ airlift pump technology is used in many global markets including water/wastewater, aquaculture, aquaponics, and hydroponics systems for water circulation and aeration.*

This case study was condensed from an in-depth study published in Aquacultural Engineering, Volume 87, November 2019, 101998.