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New Theoretical Model Predicting the Bubble Pump Performance

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1. Abstract (Times New Roman Bold 12 pt)

~~Up to date t~~<u>T</u>he existing theoretical models of the bubble pump w~~h~~ere initially developed for air lift pumps where neither heating nor separation occurs.~~-~~ Thus, the experimental results ~~that were conducted~~ for a bubble pump did not correlate well with the theoretical models. Empirical values were suggested in some of the models<u>;</u>~~,~~ however, their values varied from one system to another and could not be predicted analytically. ~~-~~In this work a modified model is presented~~.~~ with the utilization of the drift flux model with laminar flow assumption~~ is presented~~. In addition, for the first time the applied heat is expressed in the model.

Keywords: diffusion absorption cooling systems**,** bubble pump, drift flux model.

2. Introduction

Diffusion absorption cooling systems are heat driven and contain no moving parts such as a compressor or a pump. The working fluid is a mixture of a coolant and a solvent together with an inert gas. The main part of such systems is the bubble pump where heating, pumping of the solution<u>,</u> and the separation occur~~s~~.~~-~~ The bubble pump is a heated tube (length L and diameter D) connecting two reservoirs (Fig. 1). Initially<u>,</u> the level of the liquid in the lift tube is~~ at~~ the same ~~level~~ as in the lower reservoir (H). Heat is supplied at the bottom of the bubble pump (generator) and causes the gaseous coolant bubbles to flow up the lifting tube. ~~-~~The heat causes reduction in the bulk density of the fluid in the tube in comparison to that in the lower reservoir<u>,</u> which creates a buoyancy effect. At the upper reservoir (the separator), the gas is separated from the liquid solution. In diffusion absorption refrigeration (DAR) systems the bubble pump is ~~the~~ responsible for the circulation of the binary solution containing a coolant (usually a refrigerant) and an absorbent (usually an organic solution). <u>Coefficient of performance (</u>COP<u>)</u> values of DAR systems are low and in the range of 0.1-0.15.

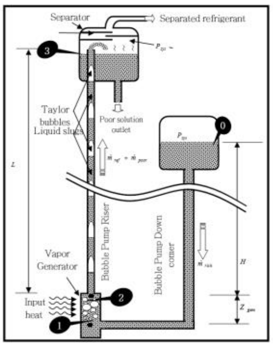

Figure 1: Schematic drawing of the bubble pump.

[1]~~First were~~ <u>were the first to</u>~~who~~ develop~~ed~~ an analytical model for an air lift pump. In their model one~~-~~dimensional mass and momentum equations together with the basic equations of two-phase flow<u>,</u> taking in<u>to</u> consideration the effects of friction and slip between the gas and liquid phases (drift flux model)<u>,</u> were used. Liquid volume flow rates were plotted versus air volume flow rates for various submergence ratios (H/L). [2] studied theoretically and

experimentally the vapor bubble pump. The model of [1] was first~~ly~~ modified to analyze the performance of the bubble pump. All the supplied heat was assumed to evaporate the water without any heat loss~~es~~. The velocity of the bubbles was assumed to be constant. ~~Also~~ [2] also used a constant value of slip factor (the ratio of velocities of the vapor and the water)~~,~~. ~~I~~[3] studied theoretically and experimentally the bubble pump performance assuming that the flow in the vertical lift tube was laminar and using K adjustable parameter to account for losses other than friction in the tube.

3. Theoretical model

The theoretical model is based on mass balances, energy balances, and one~~-~~dimensional momentum balances with drift flux model and lamina flow assumptions.

$\dot m_{gas}, \dot m_{rich}, \dot m_{poor}$ are the mass flow rates of the gas, the rich solution, and the poor solution, respectively.

From the calculations the submergence ratio is:

$$\frac{(H+Z_{gen})}{(Z_{gen}+L)} = \frac{\dot m_{rich}^{2}}{\rho_{rich}\cdot g\cdot (Z_{gen}+L)}\cdot\left[\frac{1}{2\rho_{rich}\cdot A_{DC}^{2}}+\frac{1}{A_{gen}^{2}}\cdot\left(\frac{1}{\rho_{TP}}-\frac{1}{\rho_{rich}}\right)\right]+\frac{\rho_{TP}}{\rho_{rich}} \quad (1)$$

From heat balance on the generator:

$$\dot W = \dot m_{rich}\cdot \bar c_p\left(T_{gen}-T_{res}\right) \quad (2)$$

4. Experimental Results

The model was compared with the experimental results of [4]. It can be seen from the figure that the higher the flow rates the more accurate ~~is~~ the model is. The assumption is that for higher flow rates the present of the heat losses is more negligible.

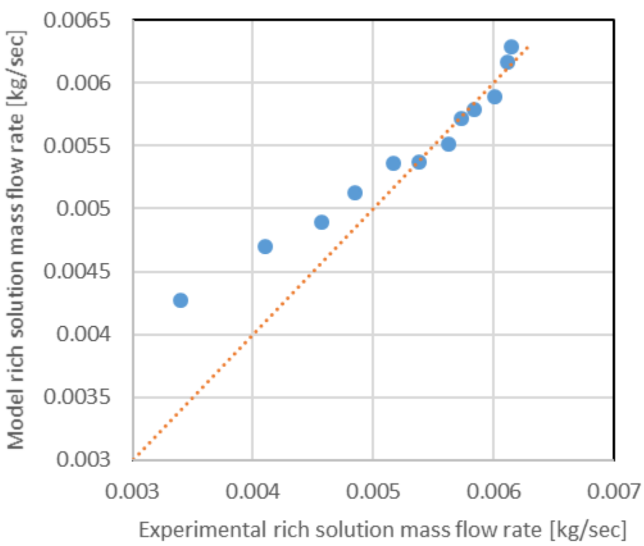

Figure. 2: Calculated rich solution mass flow rate based on the model vs. the experimental results of [4]~~]~~, h/L=0.7.

5. Conclusions

The presented model correlates between the amount of the applied heat and the rich solution mass flow rate. It is important to state, that the previous models were developed for an adiabatic aill-water lift tubes where heat did not play any significant role. The present model correlates the geometrical and the operational parameters of the bubble pump and fits better to the experimental results.

6. References

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