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Experimental investigation on the flow behaviour in a bubble pump of diffusion absorption refrigeration systems

Ali Benhmidene [a,*], Khaoula Hidouri [a], Béchir Chaouachi [a], Slimane Gabsi [a], Mahmoud Bourouis [b]

[a] URECAP, Ecole Nationale d'Ingénieurs de Gabès, Route Mednine, 6029 Tunisie
[b] Department of Mechanical Engineering – Universitat Rovira i Virgili, Av. Països Catalans No. 26, 43007 Tarragona, Spain

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ABSTRACT

An experimental investigation on the performance of a bubble pump for diffusion absorption refrigeration (DAR) systems was carried-out. The characteristics and operating conditions of the bubble pump determine the efficiency of the DAR systems. An experimental set-up operating in continuous mode was designed, built-up and successfully operated as a bubble pump. Experiments were performed by changing some of the parameters affecting the bubble pump performance. The experimental results showed that the performance of the bubble pump was mainly dependent on the driving heat input and the submersion ratio. Driving heat inputs applied were between 20 W and 200 W for a suitable size of the pump tubes. Three submersion ratios were tested, namely 25%, 35% and 45%. The results obtained showed that an oscillating flow was present in the operation of the bubble pump and the frequency of oscillation increased with the increase of the submersion ratio. The average mass flow rate of the refrigerant (ammonia) pumped increased with increase in the heating power; however, mass flow rates of the poor and rich solutions were function of the flow regime. In addition, experimental results were used to determine the optimal heating power for the different submersion ratios considered in this study. The optimal heating power ranged from 30 W to 130 W for a submersion ratio of 25% and from 30 W to 80 W for the submersion ratios of 35% and 45%.

1. Introduction

In diffusion absorption refrigeration (DAR) systems, a thermally driven bubble pump is used to circulate the solution from the absorber to the generator. A bubble pump is simply a vertical tube in which liquid and vapour streams coming from the boiler or generator are introduced at the bottom. The liquid phase fills the lift tube to a predefined height. The vapour phase circulates upwards through this section and forms bubbles that act like pistons driving up the liquid in the remainder section of the tube. The bubble pump is a key component in diffusion absorption refrigeration systems.

Benhmidene et al. [1] reviewed bubble pump configurations from the heating mode point of view. The first configuration reported by the authors is a single lifting tube where the heat input is restricted to a small heating zone at the bottom.

* Corresponding author.
E-mail address: ali.benhmidene@gmail.com (A. Benhmidene).

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Another configuration consists of various lifting tubes, integrated with a flat plate solar collector or indirectly heated bya heat exchanger.

Zohar et al. [2] carried out a thermodynamic analysis to study the effect of three different configurations of the generator and bubble pump on the performance of DAR systems. They concluded that the configuration integrating both the generator and the bubble pump was of great interest.

Two-fluid model was employed by Benhmidene et al. [3,4] to investigate the influence of heat input on a uniformly heated bubble pump at different operating conditions. The optimum heat input was correlated as a function of the tube diameter and mass flow rate, whilst the minimum heat input required for pumping the liquid was correlated as a function of the tube diameter. In addition, Benhmidene et al. [5] investigated the influence of the geometry parameters and operating conditions such as tube diameter, pressure, and ammonia mass fraction in the solution at the bubble pump entrance on the flow parameters at the bubble pump exit. The authors concluded that tube diameter is the parameter that most influences the bubble pump operation.

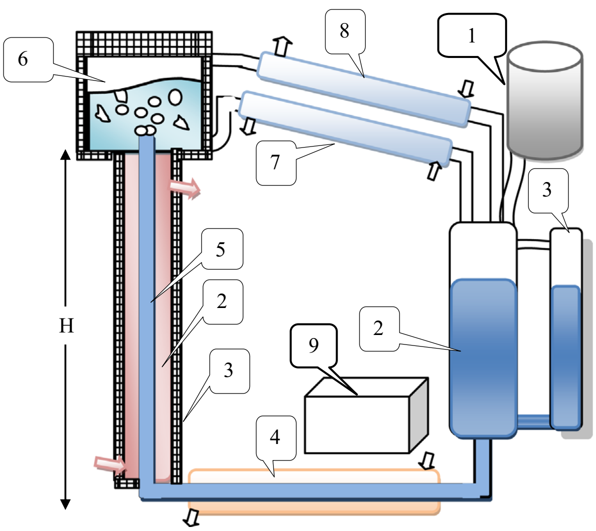
Ma et al. [6] used the two-fluid model to describe the two-phase flow and heat transfer process in a two-phase closed thermosyphon. They reported that flow patterns predicted numerically and distribution of parameters under different operating conditions showed a good agreement with experimental results.

The uniformly heated tube configuration of the bubble pump was numerically investigated by Garma et al. [7] using the commercial CFD (Computational Fluid Dynamics) tool ANSYS/FLUENT. The effect of heating distribution on the boiling flow of water in a vertical tube showed that the void fraction was higher when the wall was partially heated. Flow regimes repartitions were identified based on the void fraction variation along the tube.

Soo et al. [8] carried out a multidimensional numerical simulation of the saturated flow boiling heat transfer in bubble pumps of diffusion absorption refrigeration cycles. The bubble pump consisting of a vertical tube was uniformly heated at the outer wall surface along the entire pump length. The authors concluded that their numerical model predicted more realistically the performance of ammonia/water bubble pumps than the one-dimensional model.

Pfaff et al. [9] studied the bubble pump for a water/lithium bromide absorption cooling cycle. They developed a mathematical model using the manometer principle to evaluate the bubble pump performance. They reported that the pumping ratio was independent of the heat input. However, the frequency of the pumping action increased when the heat input to the bubble pump was increased, or if the tube diameter was decreased. The model was then used to analyse an ammonia/water bubble pump. The results indicated that the diameter maximizing the efficiency of the bubble pump was between 4 mm and 26 mm for a liquid pumping rate between 0.0025 kg s^{-1} and 0.02 kg s^{-1}. However, the efficiency rapidly decreased when diameters lower than the values of the optimum range were used; therefore they recommended that the diameter should be slightly higher than the values of the optimum range.

Rattnerand Garimella [10] presented an experimental study of a 7.8 mm internal-diameter bubble-pump generator with water-steam as a working fluid over a wide range of operating conditions. This bubble-pump generator could be operated with heat input temperature as low as 11 °C above the fluid saturation temperature. A mechanistic fluid flow and heat transfer model was developed and validated. This investigation demonstrated that integrated fluid-heated bubble-pump



1: Solution preparation tank; 2: Solution reservoir; 3: Level indicator; 4:Heat exchanger; 5: Bubble pump; 6: Separator; 7 Condenser; 8: preheater, 9: Thermostatic bath, 10: heating fluid, 11: insulation

Fig. 1. Technical drawing of the experimental set-up.