Experimental investigation on a hybrid enhanced surface generator performance

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ABSTRACT

Several studies present the performance and analyze the heat and mass transfer along falling film tubes, but usually smooth surface tube bundles are analyzed and experimental work is required if enhanced surfaces are considered. This paper presents the design of a test rig used for thermal characterization of an Absorption Heat Transformer's low pressure components, i.e. generator and condenser. The generator is designed as a hybrid falling film – pool boiling heat and mass exchanger. Performance and feasibility of using enhanced tubes for the generator is analyzed for both heat exchangers independently.

1. INTRODUCTION

Absorption Heat Transformers (AHT) offer an interesting opportunity for industrial waste heat recovery, being able to increase the temperature of approximately 50% of the waste energy by approximately 50 K. These systems use heat and mass exchangers and usually operate with the water-lithium bromide solution pair. Falling film configuration is suitable for water-lithium bromide exchangers due to its high heat exchange potential and associated low pressure drop which is vital considering that AHT operates in vacuum conditions. However, falling film presents some issues, e.g. correct solution distribution, to ensure sufficient tube wetting, optimal space between tubes and their diameter and surface type. On the other hand, pool boiling configuration can reach higher heat transfer coefficients and thus smaller heat exchanger area is required, having the drawback of needing a higher solution charge.

2. EXPERIMENTAL TEST BENCH

The generator-condenser test rig operates in continuous mode, where the water vapor desorbed from the solution is condensed and mixed again with the concentrated solution. Heating and cooling water are supplied to the generator and condenser, respectively.

The falling film part of the generator to be tested in this work is made of four columns of twelve horizontal copper low finned tubes of 15.9 mm outer diameter (GEWA-K-1908.14070-22 from Wieland-Werke AG[1]), with 500 mm useful length. The pool boiling part consists of sixteen of the same type of tubes. These enhanced surface structures influence the characteristics of the liquid film flow and are expected to significantly enhance heat transfer. The design of the solution distributor was taken from Álvarez [2], where different configurations of distributors where analyzed, to ensure a uniform wettability of the tube bundle. This is formed by 49 2 by 7 mm slots, having a separation of 3 mm between them.

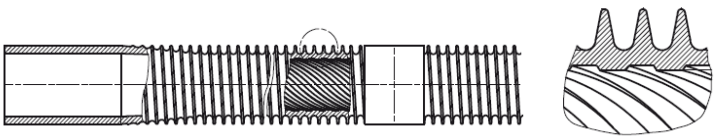

Figure 1: Scheme of the enhanced surfaces used for Falling-Film and Pool-Boiling Generators.

3. RESULTS AND DISCUSSION

Tests in falling film mode with variable solution flow rate (per tube unit length) have been conducted, between 0.005 and 0.033 $kg \cdot m^{-1} \cdot s^{-1}$ ($\Gamma=\dot{m}/L$), corresponding to a film Reynolds number between 7.84 and 65.85, and maintaining constant external heating and cooling water temperature (95ºC for generator and 25ºC for condenser) and flow rates (inlet water velocities up to 1m/s for generator and around 1.4 m/s in the condenser). Tests were performedwith LiBr molybdate inhibited solution entering the generator at concentrations near to

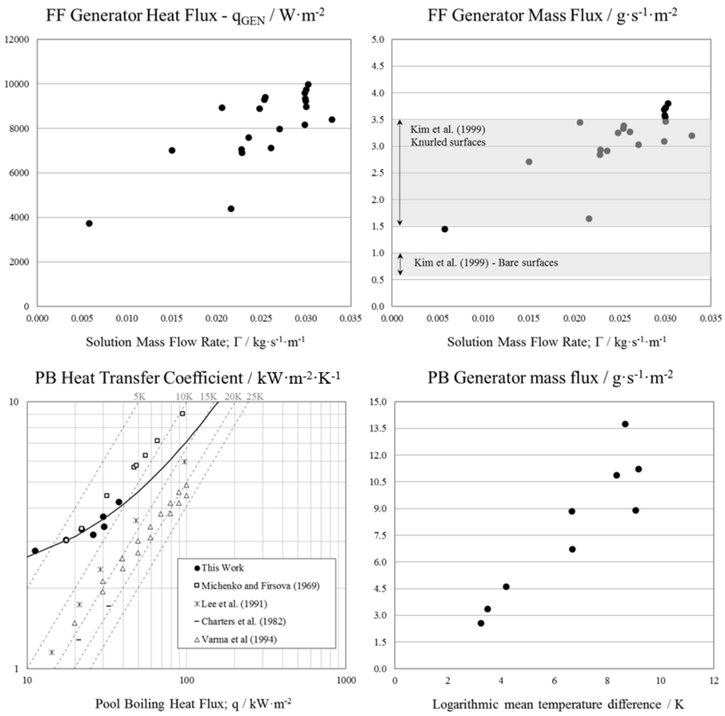

Figure 2: Falling film (FF) and pool boiling (PB) generators performance: heat and mass transfer fluxes.

55%, and sub-cooling state between 1.4 and 5.2 K. Results show an increase in heat flux and overall heat transfer coefficient with increasing mass flow rates, reaching a heat flux between almost 4,000 and a maximum of ~10,000 W·m^{-2} and mass transfer fluxes of between 1.40 and 3.80 g·m^{-2}·s^{-1}, when mass flow rate is increased. Kim et al. (1999) [3] studied heat transfer characteristics of the enhanced copper tubes: knurled and spirally grooved tubes. Results obtained by authors with enhanced knurled surfaces laid between 1.44 and 3.5 g·m^{-2}·s^{-1}, which are in good agreement with values in this work.

Tests in pool boiling have been performed to analyse generator performance under different external water inlet temperatures, between 80 and 105 ºC. The solution enters the generator with a constant solution flow rate (~ 0,04 kg·s^{-1}) and inlet concentrations near to 55%, between 53.49 and 55.11%. External water flow rates have been maintained, obtaining internal velocities of 1.06 m/s and 1.39 m/s for pool-boiling generator and condenser respectively. Results in pool boiling mode show a linear increase in heat flux, obtaining heat fluxes between ~11,500 and 36,500 W·m^{-2}, reaching a mass transfer fluxes of between 4.62 and 13.76 g·m^{-2}·s^{-1}. Graph in Figure 2 presenting heat fluxes shows the comparison of several authors results collected by Estiot et al. (2005) [4]. Under the range of 5−10K the performance agrees with data obtained by other authors, although the heat transfer fluxes are being higher for other authors in the same range temperature differences.

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REFERENCES

[1] Wieland-Werke. Low Finned Tubes catalogue. Page11. http://www.wieland-thermalsolutions.com.

[2] Álvarez Bermúdez, M.E. Estudio teórico y experimental de la solución acuosa de nitratos de litio, sodio y potasio como fluido de trabajo en enfriadoras de absorción con accionamiento de alta temperatura. Tesis Doctoral. Universidad Rovira i Virgili.

[3] Kim, D., & Kim, M. H. (1999). Heat transfer enhancement characteristics for falling-film evaporation on horizontal enhanced tubes with aqueous LiBr solution. Journal of Enhanced Heat Transfer, 6(1).

[4] Estiot E., Natzer S., Harm M., Kren C., Schweigler C. (2005) Heat exchanger development for compact water/LiBr sorption systems. Internation sorption heat pump conference. June 22-24, Denver, CO, USA.