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Analysis of effective wetting area of a horizontal generator for an absorption heat transformer

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HIGHLIGHTS

- We use image processing for analysis of effective wetting area.
- We analyze the effective heat transfer area for heat absorption in horizontal pipes.
- We analyze of film thickness during $LiBr-H_2O$ flow in horizontal pipes.

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ABSTRACT

The use of thermal processes for water purification is a good alternative to reduce primary energy consumption. The efficiency in heat exchange process by falling film plays a very important role in the performance of a heat pump. The objective of this paper is to evaluate the efficiency of heat transfer on a tube bank, of a heat transformer designed for water purification with $LiBr-H_2O$ as absorbent mixture, by digital image processing. To analyze the wetting area and falling film behavior of the mixture on a bank of sixteen horizontal tubes, of 1.22 cm outer diameter and 30 cm in length, experimental tests were performed. The results show the distribution of absorbent mixture, along the tubes of the bank, with 0 and 5° inclination respect to the horizontal, and different mass flow rates per unit length (0.006–0.034 kg/m s). The film thickness of $LiBr-H_2O$ was determined by the digital image processing, obtaining an average value of 0.033 cm. The most regular fall of mixture, through the tubes of the bank, was obtained with the flow of 0.025 kg/m s. This mass flow was the one which gave the best results of efficiency of heat transfer, with values between 80 and 98%.

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1. Introduction

In heat pumps applied for water purification, we can highlight two important aspects: the use of alternative energy sources and the design of devices that help to make more efficient use of energy. One advantage of heat transformers by absorption is that they can work at lower grade energy levels than fossil fuels. For this reason, and because it can use waste heat as energy source, they are used increasingly in industry [1].

An absorption heat transformer is mainly composed of four heat exchangers: generator, condenser, evaporator and the absorber. In the absorption cycle of heat, the generator has a key role since this device provides the generation of the steam needed for the exothermic reaction in the absorber, and thus the heat for a specific application is obtained. In the case of heat exchangers falling film, it is known that a homogeneous distribution of the film on the heat exchange surface increases the efficiency for these devices [2].

The absorption pumps, which use water as a working fluid and lithium bromide as absorbent mixture, are widely used. However, there are some aspects which require further investigation: the relationship between the falling film regime through horizontal tubes, the film thickness of the absorbent mixture, the efficiency of humidification, and the heat exchange process in the bank tubes.

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Table 1
Geometry and operating conditions.

Tube outer diameter D_{ex}	1.22 cm
Tube inner diameter D_{in}	1 cm
Tube length L	30 cm
Length bank L_B	27.5 cm
Number in vertical arrangement of tubes	16
Surface structure	smooth
Distance between tubes S_t	0.5 cm
LiBr–H_2O inlet temperature $T_{LiBr-H2O}$	20 °C
LiBr inlet mass fraction $X_{LiBr-H2O}$	55%
LiBr–H_2O inlet density $\rho_{20°C}$	1616.0 kg/m^3
LiBr–H_2O inlet dynamic viscosity μ	0.0029 kg/m s
Mass flow rate per unit length Γ	0.006, 0.015, 0.025, 0.034 kg/m s

Energy efficiency in the heat exchange process of the generator is determined by the areas of wetting of the mixture of LiBr–H_2O. To evaluate the performance of the falling film of the mixture of LiBr–H_2O in the bank of horizontal stainless steel tubes, an acrylic distributor with 68 holes of 0.08 cm in diameter was used. To achieve a constant and uniform flow of the mixture along the bank of tubes, the distributor was aligned to 1.0 cm of the first tube, and it was connected to a magnetic pump.

2. Experimental layout

Experimental tests on the falling film of LiBr–H_2O mixture were conducted, at four mass flows per unit length (0.006, 0.015, 0.025 and 0.034 kg/m s), at a bank of sixteen horizontal smooth tubes. Two arrangements of the tube bank were evaluated, with 0 and 5° inclination respect to the horizontal one, and the efficiency of heat exchange was compared. Table 1 shows the operating conditions and the characteristics of the tube bank.

From the results of experimental tests carried out previously with the pump, using a helical pattern in the distributor (Demesa 2012), it was decided to test a horizontal tube bank, so a new distributor was designed decreasing: the diameter of the tube, the diameter of the holes and the spacing between them.

Fig. 1. Falling film behavior.

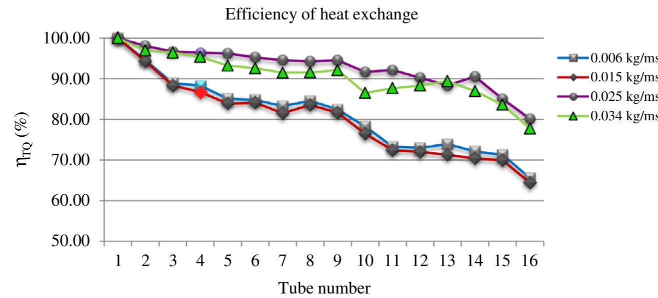

Fig. 2. Efficiency of heat exchange with 0° inclination.

The distributor of the tubes bank was built with an acrylic tube of 0.64 cm of inner diameter and a length of 32 cm. The holes diameter was 0.08 cm, while the spacing between them, was 0.5 cm, so there were a total of 68 holes in an effective length of 30 cm. It was placed at 1 cm of the first tube of the bank.

The effective area of heat exchange was determined by digital image processing, taken with a high definition camera, in each tube of the bank. The wetted area was obtained from the difference between total area of each tube and dry areas identified on each one. The total effective area of heat exchange was the summation of all tubes values.

The analysis of the efficiency of heat transfer is conducted from the second tube of the bank, because the first tube directly receives the flow of LiBr–H_2O from the distributor, being completely bathed. The total area of heat exchange surface of the tubes of the bank was determined by the following equation:

$$A_T = n(\pi D_{ex} L) \tag{1}$$

where A_T is the total area of heat exchange in cm^2, n is number of tubes, D_{ex} is tube outer diameter in cm and L is tube length in cm.

The heat exchange efficiency was calculated by the following equation [3]:

$$\eta_{TQ} = \frac{A_{ef}}{A_T} * 100 \tag{2}$$

where η_{TQ} is the efficiency of heat exchange as %, A_{ef} the effective area of heat exchange in cm^2 and A_T is the total area of heat exchange in cm^2.

The film thickness was measured experimentally, using digital images processing for the four work flows, with 0° inclination, at

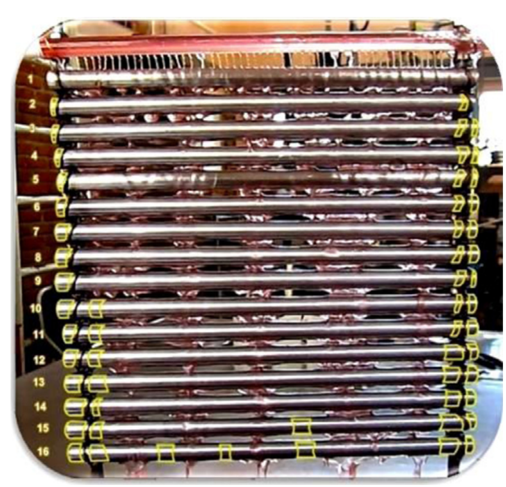

Fig. 3. Mass flow of 0.025 kg/m s.

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