

Experimental investigation of a plate heat exchanger model for lithium bromide absorption chillers: first results

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Abstract. In this paper the results of thermal-hydraulic tests of a sample of a perspective plate heat exchanger under the conditions of LBAHT is described. Working opportunity of the sample working under conditions of LBAHT has been confirmed by this research.

1 Introduction

Now, the cost reduction and the energy efficiency enhancement of lithium bromide absorption heat transformers (LBAHT) are very important problems.

The enhancement of economic and exploitation characteristics are possible by increasing of solution heat exchanger efficiency. In this regard, as an alternative to shell-tube exchangers plate type exchangers are increasingly used for recuperation of heat of weak and strong solution in LBAHT.

This is due to the fact that at the same heating surface the plate heat exchanger has a relatively high energy efficiency, compactness and significantly lower capacity for an aqueous solution of lithium bromide salt is absorbent continuously rising in price.

In this way, the use of a plate heat exchanger in the construction of LBAHT is of undoubted interest because leads to a significant reduction in capital costs for the manufacture of LBAHT and increased energy efficiency in the operation of LBAHT.

There is high operational reliability demands such as tightness and corrosion resistance are subjected to heat exchangers of LBAHT. For this, sealed, brazed or welded heat exchangers with plates of corrosion-resistant material are usually used.

The relevance of the experimental study is due to the fact that there is no universal dependence for the analytical evaluation of thermal hydraulic characteristics depending on the fluid flow regimes in the channel for complicated configurations of the heat exchange surfaces [1-3].

2 Experimental setup

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Within the framework of this project an experimental setup for the study of the thermal and hydraulic characteristics of the heat exchange equipment of LBAHT has been developed and manufactured. Schematic diagram of the setup is shown in Fig.1.

LiBr solution with 55% mass concentration are circulated through closed loop through the test model of plate heat exchanger 1, plate heat exchanger for cooling of LiBr solution 5, pre-heater of LiBr solution 3. To circulation of LiBr solution the LiBr circulation pump 2 is used. Flow rate of LiBr solution is regulated with adjusting valve 4 and controlled with flow-meter 9.

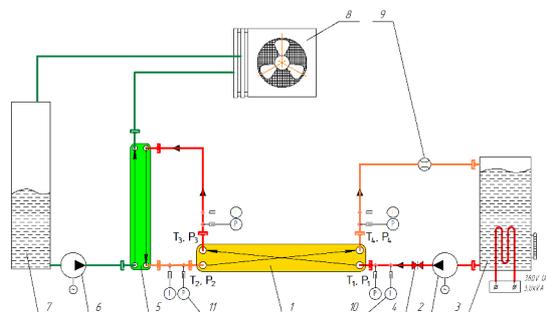


Fig. 1. Schematic diagram of the for the study of the thermal and hydraulic characteristics of the heat exchange equipment of LBAHT: 1 – test model of plate heat exchanger; 2 – LiBr circulation pump; 3 – pre-heater of LiBr solution; 4 – adjusting valve; 5 – plate heat exchanger for cooling of LiBr solution; 6 – pump of cooling liquid; 7 – tank of cooling liquid; 8 – air-cooled heat exchanger; 9 – flow-meter; 10 – temperature sensor; 11 – pressure sensor.

Heating and temperature adjusting of LiBr solution are performed in pre-heater 3 with resistive heater element. Heat capacity adjusting is performed by changing of voltage.

Cooling of LiBr solution are performed in heat exchanger 5 by water. Circulation and cooling of water are performed by the pump of cooling liquid 6, tank of cooling liquid 7 and air-cooled heat exchanger 8. Cooling capacity adjusting is performed by changing of speed of fan by frequency controller.

Measure of temperature difference through the test model is performed with resistive temperature converter Pt100. Measure of pressure drop (hydraulic resistance) – with pressure sensors with current signal 4-20 mA.

2.1 Test model of plate heat exchanger

Construction of the test model of plate heat exchanger is shown on **Fig. 2**.

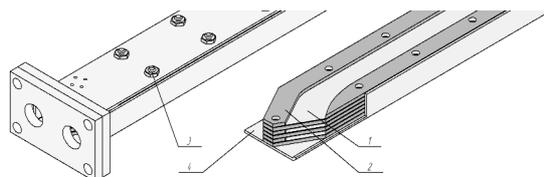


Fig. 2. Appearance of the test model.

1 – flat plate; 2 – gasket, 3 – bolted joints; 4 – part of housing.

The test model is consisted from flat plates and gaskets. Distance between plates “h” is 3 mm. The channel width “b” is 20 mm, the length is 1000 mm. The number of passes is 1, the number of channels in the pass is 3. The package of plates and gaskets is connected by means of glue and is tightened by bolted joints. As a result of joining plates and gaskets slot channels of rectangular cross section are formed.

3 Test results

The investigation of hydraulic and heat exchange characteristics of plate heat exchanger were conducted under conditions of heat recuperation of LiBr solution with concentration 55% (mass.).

Experiments has been carried out by scale imitation of processes of heat recuperation of LiBr solution under conditions of LBAHT. For this at the outlet of the pre-heater 3 temperature of «strong» solution was maintained within from 85 to 90 °C. Temperature of «weak» solution was maintained within from 35 to 40 °C at the outlet of the heat exchanger 5.

Dependences of the pressure drop ΔP and the overall heat transfer coefficient on the Reynolds number in a 3 mm-height rectangular channel are shown on Fig. 3.

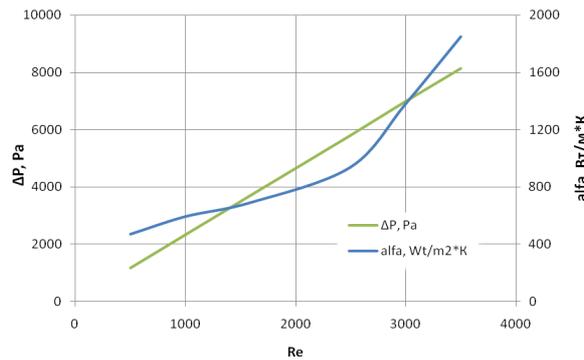


Fig. 3. Pressure drop and overall haet transfer coefficient depending on Reynolds number of 55% LiBr solution.

Reynolds number is determined as

$$Re = \vartheta_{LiBr} \cdot d_e \cdot \nu_{LiBr}^{-1} \quad (1)$$

where “ ϑ_{LiBr} ” is flow rate in channel, “ ν_{LiBr} ” is the kinematic viscosity of LiBr solution, “ d_e ” is the equivalent diameter of a rectangular channel:

$$d_e = \frac{2 \cdot h \cdot b}{h + b} \cong 2 \cdot h, \text{ (when } b \gg h) \quad (2)$$

Mean pressure drop “ ΔP ” was found as:

$$\Delta P = \frac{(P_1 - P_3) + (P_2 - P_4)}{2} \quad (3)$$

The intensity of the heat exchange process was determined by solving the system of equations (4)-(6)

$$Q_h = G \cdot c_p \cdot (T_1 - T_3) \quad (4)$$

$$Q_c = G \cdot c_p \cdot (T_2 - T_4) \quad (5)$$

$$Q_h \cong Q_c = Q \quad (6)$$

In the equations (4)-(5), “ G ” is the mass flow rate of the hot and cold fluids, “ T ” is the inlet and outlet temperature, “ c_p ” is the specific heat capacity

Heat load of plate heat exchanger was calculated as:

$$Q = K \cdot F_{HE} \cdot \Delta T_{LMTD} \quad (7)$$

where “ F_{HE} ” is area of plate heat exchanger, “ ΔT_{LMTD} ” is the temperature difference, “ K ” is the overall heat transfer coefficient:

$$\frac{1}{K} = \frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2} \quad (8)$$

In the above equation “ λ ” is the thermal conductivity of the plate, “ δ ” is the thickness of the plate, “ α_1 ” is the cold liquid, and “ α_2 ” is the hot liquid.

Mean-logarithmic temperature difference between hot stream and cold stream was calculated as:

$$\Delta T_{LMTD} = \frac{(T_1 - T_3) - (T_4 - T_2)}{\ln((T_1 - T_3)/(T_4 - T_2))} \quad (9)$$

«alfa» has been determined guided by the following assumption (8):

$$\alpha_1 \cong \alpha_2 = \text{alfa} \quad (10)$$

Assumption (10) was made due to the complete geometric equality of the “hot” and “cold” channels of the heat exchanger and the fact that the same fluid circulated in the channels.

The correction for changing the properties of the LiBr solution was not taken into account.

So, «alfa» is

$$\text{alfa} = \frac{2}{\frac{1}{K_1} - \frac{\delta}{\lambda}} \approx 2 \cdot K \quad (11)$$

4 Conclusions

The tests of the experimental sample proved the functionality of the chosen design under conditions of operation with an aqueous solution of lithium bromide. The results are well agreed with the estimated calculation [5].

Thus, plate heat exchanger with flat plates can be an alternative to a shell-tube heat exchanger of LBAHT, because plate heat exchangers having satisfactory thermo-hydraulic characteristics have a significantly lower volume of an absorbent.

Further work will be devoted to improving the thermal and hydraulic characteristics of the plate heat exchanger for LBAHT: plates containing convex-concave turbulence structures with different hydraulic channel diameters will be tested.

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