HEFAT2007
5th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
Sun City, South Africa
Paper number: CK1

EFFECT OF TUBE ARRANGMENT ON THE PERFORMANCE OF A HIGH TEMPERATURE GENERATOR OF THE ABSORPTION SYSTEM

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ABSTRACT

The present study numerically investigated the effect of tube arrangement of the high temperature generator (HTG) on the thermal performance of a double effect LiBr-water absorption system with the cooling capacity of 210 refrigeration tons. The HTG tubes were located after a metal fiber burner. The HTG was consisted with a set of circular tubes and flattened tubes in series. LiBr aqueous weak solution was flowed into the generator tube, and then turned to strong solution at the exit of the HTG tubes. FLUENT, as a commercial code, was used to estimate the thermal performance of the HTG. Standard k-ε model was applied for combustion gas-side turbulent flow around the HTG tubes. Key parameters were size of the circular tubes and spacing ratio of flattened and circular tubes in HTG. Temperature and velocity profiles around the tubes of the HTG with the same total heat transfer area were calculated to estimate the thermal performance of the HTG and to find out the optimal condition. The minimum exhaust temperature of the HTG was 214℃ at the spacing ratio of flattened tube of 0.73.

INTRODUCTION

Recently, an absorption system with LiBr aqueous solution paid attention to an air-conditioner without using chlorofluorocarbons due to the environmental problems. A high temperature generator, as one of the major components of the double-effect absorption system, strongly affects on the absorption system performance and the size. It is mainly categorized into two regions, such as combustion and evaporation regions. The high temperature generator with gun-type burner demands a large combustion chamber because of long flame. Generally, the conventional high temperature generator with gun-type burner for high cooling capacity has been widely used for the absorption system with LiBr aqueous solution. It is hard to reduce the physical size of combustion chamber of the high temperature generator with gun-type burner. A new type high temperature generator with the pre-mixed surface flame might reduce its size.

Some experimental and analytical studies had been done on the high temperature generator with gun-type burner. Furukawa et al. [1] experimentally presented the characteristics of forced convection heat transfer in the commercial high temperature generator.

NOMENCLATURE

C	[wt%]	LiBr-H2O solution concentration
c_P	[kJ/kgK]	Constant-pressure specific heat
d	[m]	Diameter of tubes
k	[W/mK]	Thermal conductivity
L	[m]	y direction distance
$\dot{m}$	[kg/s]	Mass flow rate
P	[N/m2]	Pressure
s	[m]	Spacing
T	[℃]	Temperature
U	[m/s]	Average velocity
u	[m/s]	Local velocity
W	[m]	x direction distance

Greek symbols

μ	[Ns/m2]	Viscocity
ρ	[kg/m3]	Density

Subscripts

aq	LiBr-H2O solution
c	Circular tube
f	Flattened tube
g	Combustion gas
i	x-direction
j	y-direction

Jung and Park [2] also studied temperature profile and heat

Table 1. Parametric values for numerical calculation

Parameters \ Case No.	1	2	3	4	5	6	7
$d_c / d_{c,ref}$	1	1.14	1.34	1	1	1	1
$s_{r,c} / s_{t,c}$	1.11	1.11	1.11	0.73	1.54	1.11	1.11
$s_{r,f} / s_{t,f}$	0.73	0.73	0.73	0.73	0.73	1.30	1.74

transfer rate in the high temperature generator. Lee et al. [3] numerically calculated concentration profile of LiBr solution in the high temperature generator with respect to the diameter of heat transfer tubes. An experimental study on the high temperature generator with pre-mixed surface flame burner for 5 USRT was conducted by Jung and Park[4]. However, the new type high temperature generator with pre-mixed surface burner has been rarely reported so far.

The present study investigated the effect of tube arrangement on the performance of the high temperature generator with the pre-mixed surface flame by using commercial code, FLUENT [5].

NUMERICAL MODELING AND GOVERNIG EQUATIONS

The schematic diagram of the tubes in the high temperature generator with the pre-mixed surface burner is shown in Figure 1. The high temperature generator was divided into five regions, such as combustion region(Ⅰ, Ⅲ), circular tubes region(Ⅱ), flattened tubes region(Ⅳ) and exhaust gas exit regeion(Ⅴ). The special size of combustion region is required for reducing emission gases, such as CO_x and NO_x. The heat transfer tubes of high temperature generator consisted with a bunch of staggered circular tubes and in-line flattened tubes. Circular tubes with the outer diameter of 34mm ($d_{c,ref}$) were arrayed in 4 ×8 staggered array, while flattened tubes with the width of 220mm and height of 30mm were positioned in 4×10 in-line array. The spacing ratio, s_r / s_t, as one of the key parameters, was defined as the ratio of the pitch between the cylinder wall and circular tube, s_r, to the transverse pitch, s_t. It was expressed as $s_{t,c}$ and $s_{r,c}$ for circular tubes and $s_{t,f}$ and $s_{r,f}$ for flattened tube. The other key parameter was the diameter of the circular tube(d_c). Table 1 shows the parametric values for seven different cases. They have the same heat transfer area of 14 m^2. The following continuity, momentum and energy equations were applied for the numerical study.

$$\frac{\partial(\rho U_i)}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial}{\partial x_j}\left(\rho U_j U_i\right) = -\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left\{\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right\} \tag{2}$$

$$\rho c_p\left\{\frac{\partial}{\partial x_j}\left(\rho u_i T\right)\right\} = \frac{\partial}{\partial x_j}\left(k_g \frac{\partial T}{\partial x_i}\right) \tag{3}$$

Combustion gas was assumed as an ideal gas at the steady state.

Inlet and outlet conditions of the high temperature generator and the concentration and the temperature of the LiBr aqueous solution were summarized in Table 2. The mass flow rate of combustion gas was constant as 0.34kg/s at full load. The temperature of LiBr aqueous solution was assumed as the saturation temperature at the concentrate of 56wt%. The standard k-ε model was used with turbulence intensity of 5%.

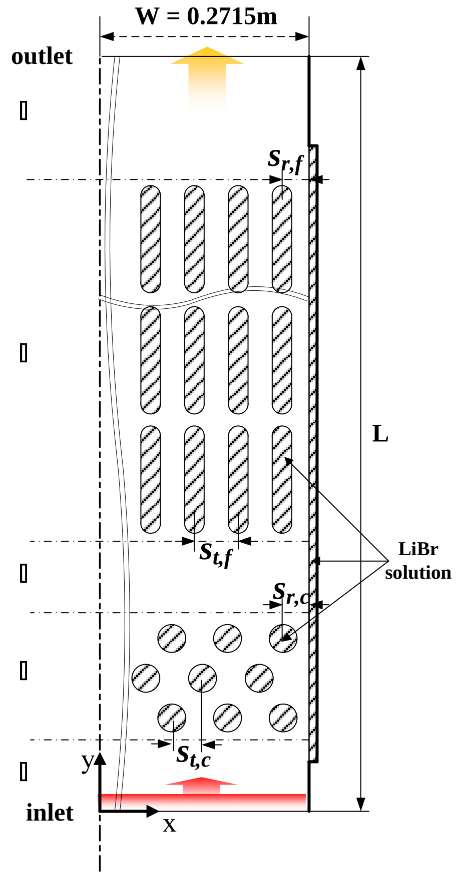


Figure 1 Schematic diagram of the tubes in the HTG

Table 2 Conditions for numerical study

Inlet	*T* (℃)	1860
	ṁ (kg/s)	0.34
Outlet	*T* (℃)	27
LiBr Solution	*T* (℃)	144
	C (wt%)	56

RESULTS AND DISCUSSIONS

Effect of the diameter of circular tubes (d_c / $d_{c,ref}$)

Figure 2 shows the temperature profile of the high temperature generator with respect to the diameter of the circular tube at the spacing ratio ($s_{r,c}$ / $s_{t,c}$) of 0.73. The temperature profile of the high temperature generator showed similar trend. As the tube diameter was increased, the temperature was a little bit increased. The exhaust gas temperature was almost constant.

Figure 3 shows the heat transfer rate delivered from combustion gas to the circular tubes with respect to the diameter of the circular. While the diameter of the circular tube was varied from $d_{c,ref}$ to 1.33 $d_{c,ref}$, the heat transfer rate to the circular tubes was decreased by 7%.

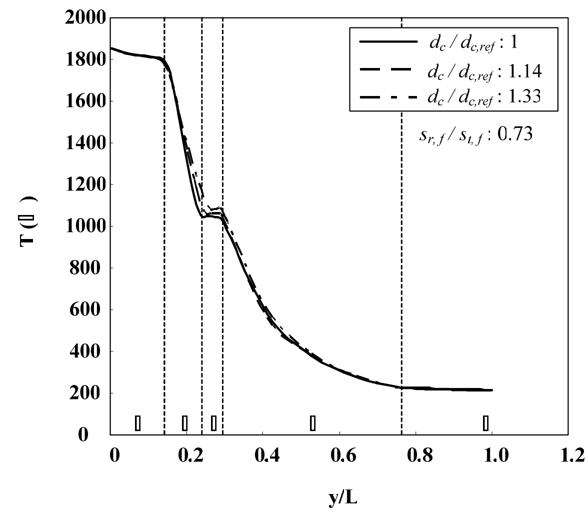


Figure 2 Effect of the diameter of circular tubes on the temperature profile

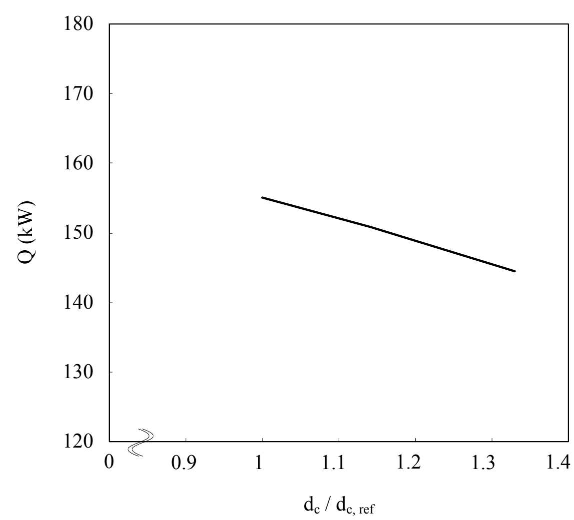


Figure 3 Effect of diameter of the circular tube on the heat transfer rate

Effect of the spacing ratio of circular tube ($s_{r,c}$ / $s_{t,c}$)

Figure 4 shows the temperature profile for different spacing ratio of circular tube. As spacing ratio was increased, the temperatures were a little bit decreased. As the spacing ratio was increased, the spacing from circular tube to the wall of inner cylinder was widened. Air flow-rate through the spacing of circular tubes was increased. It caused the decrease the temperature of combustion gas.

Figure 5 showed the heat transfer rate delivered from combustion gas to the circular tubes with respect to the spacing ratio of circular tubes. As the spacing ratio was increased, the heat transfer rate was decreased. The heat transfer rate for the spacing ratio of 1.54 (case(5)) was smaller by approximately 6% those for the spacing ratio of 1.11(case (1)).

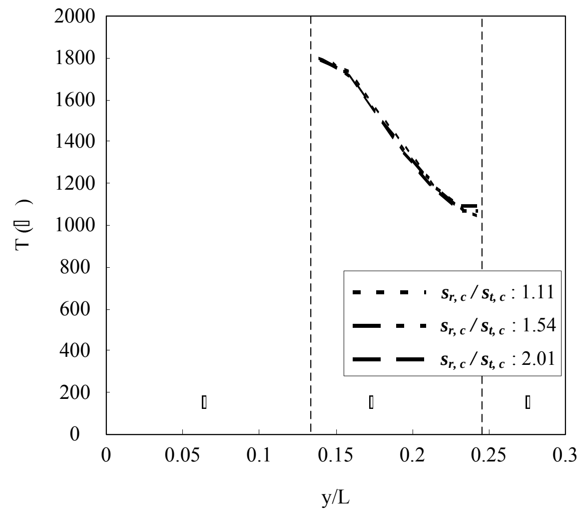


Figure 4 Effect of spacing ratio of circular tubes on the temperature profile

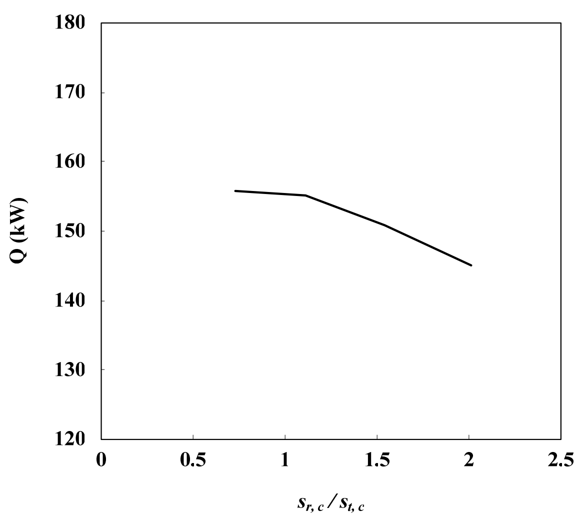
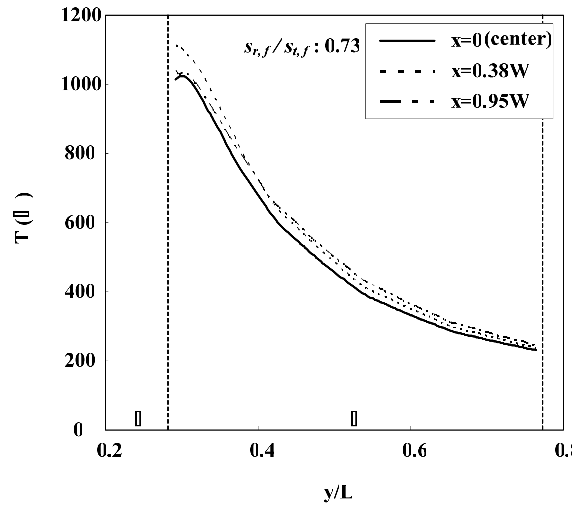


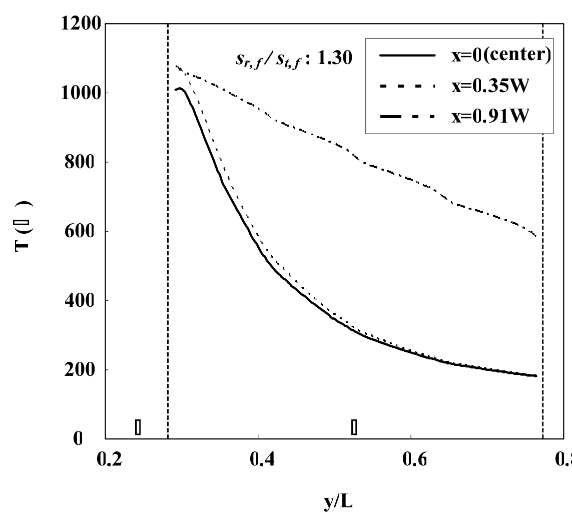
Figure 5 Effect of spacing ratio of circular tube on the heat transfer rate

Effect of the spacing ratio of flattened tubes ($s_{r,f}/s_{t,f}$)

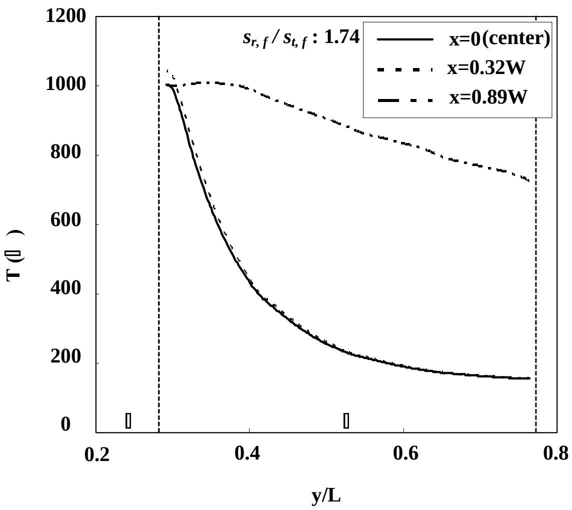
Figure 6 shows the temperature profile around flattened tubes with respect to the spacing ratio of flattened tubes. As the spacing ratio was increased, the temperature of combustion gas between the cylinder wall and the flattened tubes near the wall was increased, while the temperature of combustion gas around flattened tubes near the center of the high temperature generator was almost unchanged.



(a) case (1)



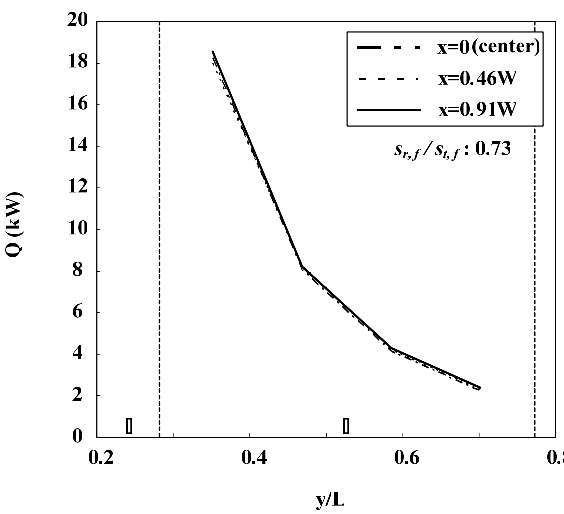
(b) case (6)



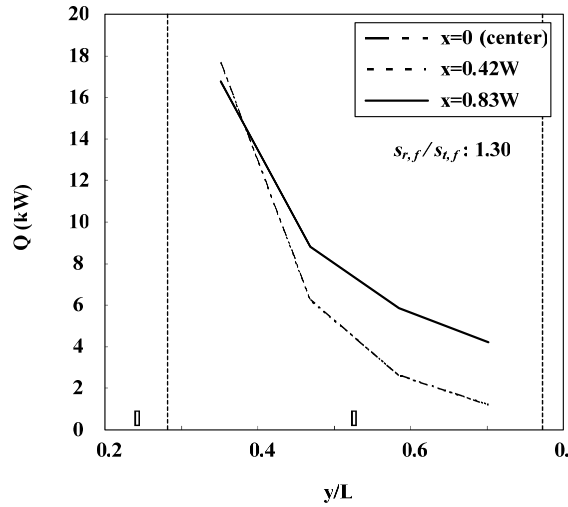
(c) case (7)

Figure 6 Effect of spacing ratio of flattened tubes on the temperature profile

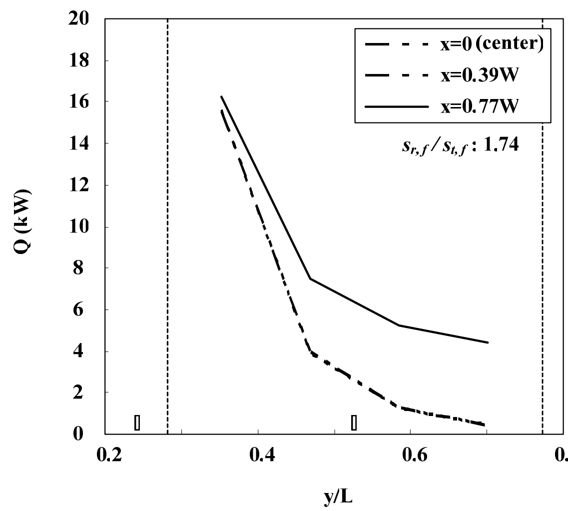
Figure 7 shows the heat transfer rate for flattened tubes with respect to the spacing ratio of flattened tubes. As the spacing ratio of the flattened tubes was increased, the difference of the heat transfer rate between the flattened tubes near the wall and the tubes near the center was increased, The heat transfer rate for the flattened tubes for the spacing ratio of 1.74 (case (7)) was smaller by the maximum of 27% than that for the spacing ratio of 0.73 (case (1)).



(a) case (1)



(b) case (6)



(c) case (7)

Figure 7 Effect of spacing ratio of the flattened tube on the heat transfer rate

CONCLUSIONS

While the diameter of the circular tube was varied from $d_{c,ref}$ to 1.33 $d_{c,ref}$, the heat transfer rate to the circular tubes was decreased by 7%.

As the spacing ratio of circular tubes was increased, the heat transfer rate was decreased. The heat transfer rate for the spacing ratio of circular tubes of 1.54 was smaller by 6% than that of spacing ratio of circular tubes of 1.11.

As the spacing ratio of flattened tubes was increased, the heat transfer rate was decreased. The heat transfer rate for the spacing ratio of flattened tubes of 1.74 was smaller by the maximum of 27% than that for the spacing ratio of 0.73

ACKNOWLEDGEMENTS

This work was supported by the Korea Energy Management Corporation(KEMCO) (grant No. 2005-E-BD11-P-05-3-010). Authors also appreciate the LS cable for providing technical data.

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