Amirkabir University of Technology
(Tehran Polytechnic)
Vol. 46, No. 1, Summer 2014, pp. 33- 35

Amirkabir Journal of Science & Research (Mechanical Engineering)
(AJSR - ME)

The Optimum Diameter of Silica- Gel Particles in Adsorption Chillers

M. Mahdavikhah[1], H. Niazmand[2*]

1- M.Sc Student, Department of Mechanical Engineering, Ferdowsi University, Mashhad, Iran
2- Professor, Department of Mechanical Engineering, Ferdowsi University, Mashhad, Iran

(Received 13 Aug 2011, accepted 01 Jul 2014)

ABSTRACT

Adsorption chillers are considered for the industrial and air conditioning applications due to their advantages over the conventional refrigeration systems. The performance of an adsorption chiller is mainly influenced by the adsorbent bed, therefore, this paper investigates a tube heat exchanger with plate fins as the adsorbent bed and silica gel(SWS-1L)-water as working pairs. In order to model the adsorbent bed, the continuity, momentum and energy equations are solved in a body fitted coordinate system and both the inter particle and intra particle mass transfer resistances are considered. The control volume method is used to solve the time dependent equations in four basic domains of thermal fluid, metal tube, fins and adsorbent bed, simultaneously. Flow patterns and pressure distributions though out the bed are examined in detail for all cycle. The results indicate that the particles diameter has a negligible effect on the coefficient of performance, while the specific cooling power and the cycle time have an optimum value for particles diameter of 0.37mm.

KEYWORDS

Adsorption Chiller, Optimization, Numerical Modeling, Silica Gel.

* Corresponding Author, Email: niazmand@um.ac.ir

1- INTRODUCTION

An adsorption chiller mainly consists of an adsorbent bed, a condenser, an evaporator and an expansion valve. The most important part of this system is the adsorbent bed, filled with porous particles capable of adsorbing and desorbing specific fluids, when the bed is cooled or heated, respectively. The performance of a double-bed adsorption chiller is well described in Ref. [1].

Due to the mass transfer resistances, the adsorbent particles diameter is also an influential parameter in the performance of an adsorption chiller. Chang et.al [2] made an experimental study to investigate the effects of adsorbent layer and particle size of silica gel on transfer processes of an adsorbent bed. They concluded that the thin layer of adsorbent made of larger sized particles improves the mass transfer performance. Glaznev [3] performed an experimental study using a metal plate covered with a monolayer of loose Fuji silica gel grains with different sizes to explore the grain size effect on the water sorption dynamics. Niazmand and Dabzadeh[4] studied the effects of particle diameter for an specified working condition on the absorbent bed performance. The considered bed was an annular finned tube heat exchanger. They indicated that SCP has an optimum value with respect to the particle diameter but COP is slightly dependent on the particle size.

Although previous studies clarified the particle size effects on the COP and SCP of adsorption chillers, however, the plate finned heat exchangers have not been studied yet. In this analysis ,a plate fin-tube heat exchanger filled with SWS-1L is employed to investigate the particle diameter effect on the performance of an adsorption chiller.

2- METHODOLOGY MODEL

To model the transport processes through an adsorbent bed, four basic domains should be solved simultaneously shown in Figure 1.

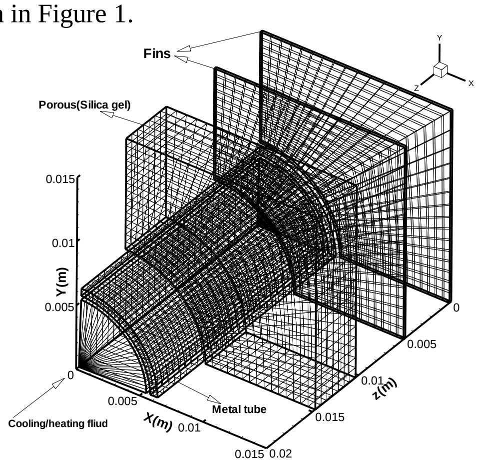

Figure 1: A magnified view of the control volumes in all different domains

Since the mechanisms of heat and mass transfer in the adsorbent bed are complicated, several assumptions are made to simplify the governing equations:

- The particles in the adsorbent bed are uniform in size, shape, and porosity.
- The thermo physical properties of thermal fluid, tube, fins, dry adsorbent, adsorbate liquid and gas are assumed to be constant, except for the density of adsorbate gas.
- No heat losses through the chamber walls are considered.
- The adsorbed phase and the refrigerant vapor are considered as a liquid and an ideal gas, respectively.
- The condenser and evaporator are assumed to be ideal with constant temperature during the isobaric phases.

The mathematical modeling of each domain is discussed in the following:

2.1. Thermal fluid:

For the simplicity and without the loss of generality only the axial temperature variation is considered. Furthermore, the axial conduction is also ignored due to the high Reynolds numbers considered for this flow.

$$\int_{CV} \rho_f C_{P_f} \frac{\partial T_f}{\partial t} d\forall + \int_{CV} \vec{\nabla}.(\rho_f C_{P_f} \vec{u}_f T_f) d\forall = -Q_{fluid-tube} \quad (1)$$

2.2. Metal tube:

For the metal tube, the transient three dimensional heat transfer equation is expressed by:

$$\int_{cv} \rho_{tube} C_{p\,tube} \frac{\partial T_{tube}}{\partial t} d\forall = \int_{cs} (\lambda_{tube} \vec{\nabla} T_{tube}).\overrightarrow{dA} - \gamma * Q_{tube-fin} \quad (2)$$

$$\int_{CV} \rho_{tube} C_{P_{tube}} \frac{\partial T_{tube}}{\partial t} d\forall = \int_{CV} \vec{\nabla}.(\lambda_{tube} \vec{\nabla} T_{tube}) d\forall + S_{tube}$$

2.3. Fins:

Since fins are very thin, heat transfer can be considered to be two dimensional in the plate perpendicular to the tube axis.

$$\int_{cv} (\rho C_p)_{fin} \frac{\partial T_{fin}}{\partial t} d\forall = \int_{cs} (\lambda_{fin} \vec{\nabla} T_{fin}).\overrightarrow{dA} - Q_{fin-b} \quad (3) \quad \int_{CV} \rho_{fin} C_{P_{fin}} \frac{\partial T}{\partial}$$

2.4. Adsorbent bed:

The most important part in modeling the adsorbent chamber is the adsorbent bed consisting of porous particles and refrigerant flowing through the bed, which requires the simultaneous solution of the continuity, momentum, and energy equations.

The energy balance for the adsorbent bed is expressed as:

$$\int_{cv} \rho C_p \frac{\partial T_b}{\partial t} d\forall + \int_{cs} (\rho_g\, C_{pg} \vec{u}_g\, T_b).\overrightarrow{dA} =$$
$$\int_{cs} (\lambda_b \vec{\nabla} T_b).\overrightarrow{dA} + \int_{cv} \rho_b \Delta H\ \frac{\partial w}{\partial t} d\forall$$

$$\int_{CV} \rho\, C_P \frac{\partial T_b}{\partial t} d\forall + \int_{CV} \vec{\nabla}.(\rho_g C_{P_g} \vec{u}_g T_b) d\forall = \int_{CV} \vec{\nabla}.(\lambda_b \vec{\nabla} T_b) d\forall + \int_{CV} \rho_b \Delta H \frac{\partial w}{\partial t} d\forall \quad (4)$$

The mass balance equation for the refrigerant is given by:

$$\int_{CV} \varepsilon_t \frac{\partial \rho_g}{\partial t} d\forall + \int_{CV} \vec{\nabla}.(\rho_g \vec{u}_g) d\forall + \int_{CV} \rho_b \frac{\partial w}{\partial t} d\forall = 0 \quad (5)$$

where w is the adsorption rate calculated by:

$$\frac{dw}{dt} = \frac{15 D_{so} \exp\left(-\frac{E_a}{R T_b}\right)}{R_p^2}.(w^* - w) \quad (6)$$

where w^* is the equilibrium uptake at the temperature T_b and pressure P.

The refrigerant vapor superficial velocity is determined by Darcy correlation:

$$\vec{u} = -\frac{K_{app}}{\mu} \vec{\nabla} P \quad (7)$$

The chamber pressure is assumed to be equal to the condenser or evaporator pressure in isobaric phases. In isosteric phases the pressure is calculated according to the following procedure: first, the total mass flow rate of the refrigerant vapor entering the chamber is determined. Then the density is calculated from the continuity equation, and finally the chamber pressure is obtained through / from adopting ideal gas equation of the state.

3- RESULTS

There are two opposing effects associated with the particle diameter. Reducing the particle diameter reduces the intraparticle resistance leading to stronger rates of heat and mass transfers to or from the particles, at the same time interparticle resistance increases, which reflects in the lower rates of the heat and mass transfer of the whole bed. Therefore, a specific diameter can be found in which the SCP is maximum, while the COP of the system remains almost constant as shown in Fig. 2.

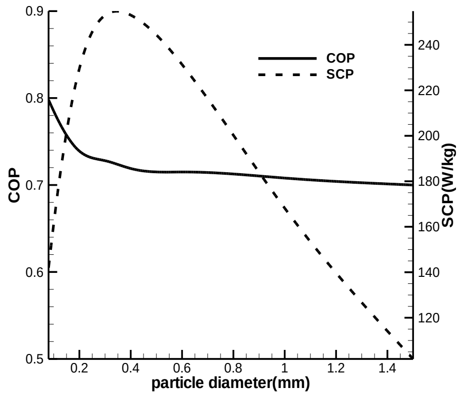

Figure 2: Variations of specific cooling power and coefficient of performance with adsorbent particle diameter.

4- CONCLUSION

This study investigates the effects of adsorbent particle diameter on the performance parameters of an adsorption chiller. The results show that the cycle time has a minimum value at the specific particle diameter which corresponds to the maximum specific cooling power of the system.

5- REFERENCES

[1] X. Wang, and H.T. Chua, “Two bed silica gelewater adsorption chillers: An effectual lumped parameter model”, Journal of Refrigeration, Vol. 30, pp. 1417-1426, 2007.

[2] K.S. Chang, M.T. Chen, T.W. Chung, “Effects of the thickness and particle size of silica gel on the heat and mass transfer performance of a silica gel-coated bed for air-conditioning adsorption systems”, Appl. Therm. Eng, Vol. 25, pp. 2330- 2340, 2005.

[3] I.S. Glaznev, Y.I. Aristov, “The effect of cycle boundary conditions and adsorbent grain size on the water sorption dynamics in adsorption chillers”, Int. J. Heat Mass Transf, Vol. 53, pp. 1893- 1898, 2010.

[4] H. Niazmand, I. Dabzadeh, “Numerical simulation of heat and mass transfer in adsorbent beds with annular fins”, Int. J. Refrigeration, Vol. 35, pp. 581– 593, 2012.