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Analysis of the icing and melting process in a coil heat exchanger

Yan Li*, Chao Yang, Zhe Yan, Bin Guo, Han Yuan, Jian Zhao, Ning Mei

College of Engineering, Ocean University of China, #238 Song Ling Road, Qingdao 266100, P.R. China

Abstract

The ice storage coil heat exchanger are analyzed based on unstable heat conduction theory, the analytical solution of solidified layer is obtained, and get the solution of the temperature distribution in both solid phase and liquid phase. Through numerical simulation, it is found that the agitator can rise the convective heat transfer coefficient of the structure and enhance heat exchange efficiency. The temperature distribution of surface of the evaporation coil during the deicing process is measured by experiment. It is found that melting phenomenon occurred at the lower part of the ice layer first, and the outer side of the ice layer melting faster than the inner side.

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Keywords: Coil heat exchanger; heat transfer analysis; icing and melting; unstable state heat conduction

1. Introduction

The coil heat transfer structure has many advantages and superior performance, it have been widely used in many areas to enhance heat exchange, Fsadni et al. (2016). The coil structure is easy to be manufactured, and on the other hand, the rigid structure of the coil ensures the stability of use, Liu et al. (2016). At present, the research on coil heat exchanger is mainly focused on two aspects: numerical simulation and experimental study. Ghorbani et al. (2010) established the coiler experimental model, the convective heat transfer of coiler was studied. Based on the experimental data, the relationship between geometric size, operating conditions, and heat transfer performance were analyzed. The research shows that heat transfer structure and velocity ratio are most important factor to affect

* Corresponding author. Tel.: +86-139-5325-9329.
E-mail address: yanli@ouc.edu.cn

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the heat exchanger efficiency. After that, the spiral coil heat exchanger with diaphragm was studied by Krasikov et al. (2011). The experimental results show that the working pressure, the gas composition and the symmetry of the flow along the tube bundle are the main factors affecting the heat transfer efficiency of the heat exchanger, and the influence of working pressure are significant. In addition, experiments were carried out by Jamshidi et al. (2013) to study the mixed convection in a vertical helical coil, and the optimum equivalent diameter of the shell side was pointed out. Jamshidi et al. (2013) studied some other aspects of the flow and heat transfer in the tube and shell side. It is found that the pitch of spiral coil, the winding diameter of spiral coil and the flow rate of fluid are the main parameters that affect the heat transfer performance of spiral coil heat exchanger.

In summary, those research has not pointed out the method to improve the efficiency of ice storage system. This paper carries out three aspects research including theoretical analysis, numerical simulation and experimental to study the ice storage heat exchanger, seeking method to improve the efficiency of ice storage, and solving the problem of clogging caused by fluid super-cooling degree.

Nomenclature

t_s, t_l	temperature of solid and liquid phase respectively, K
a_s, a_l	thermal diffusivity of solid and liquid phase respectively, m^2/s
λ_s, λ_l	Thermal conductivity of solid and liquid phase respectively, $W/(m\cdot K)$

2. Theoretical analysis of ice storage

2.1. Model of ice storage system

The ice storage system uses the phase change of the medium water to achieve the effect of cold storage and through the water coil heat transfer to obtain cooled drinking water. The system is equipped with a stirring blade to enhance convective heat transfer. Fig. 1 is the structure of ice storage cooling water system. This system are mainly composed of evaporating pipe, drinking water pipe, agitator and a container. There is a cold preservation layer on the surface of the container, and the surface can be regarded as the adiabatic condition.

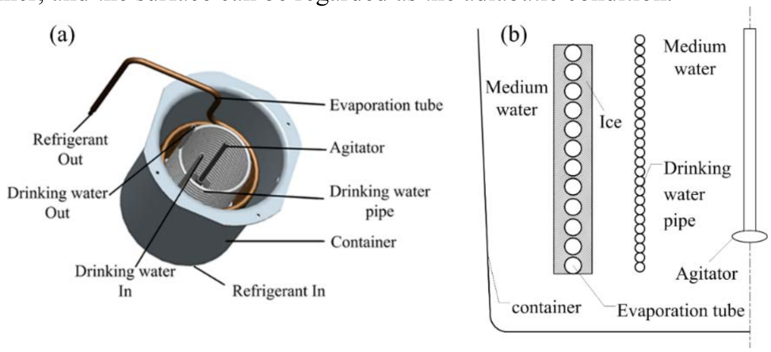

Fig. 1. Structure of the ice storage system. (a) Graphic model of the device. (b) Simplified cross section.

The container is filled with medium water, and the evaporating pipe, the drinking water pipe and the agitator blades are immersed in the medium water. The evaporator pipe is externally connected with the compressor, and the refrigerant is evaporating and absorb heat while it flow from the bottom of the coil tube into the evaporation tube, so that the water in the container is frozen and adhered to the surface of the evaporating pipe, and the cold is accumulated. And in another circulating system, drinking water is flow in the water coil, release heat and reduce its temperature. During the freezing process, the agitation of the blades will prevent the formation of temperature stratification, so that the thickness of the ice layer outside the evaporator tube would be uniform.