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# Artificial boiling heat transfer in the free convection to carbonic acid solution

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ABSTRACT

Free convection phenomenon has been experimentally investigated around a horizontal rod heater in carbonic acid solution. Because of the tendency of the solution to desorb carbon dioxide gas when temperature is increased, bubbles appear when cylinder surface is heated. The bubbles consists mainly carbon dioxide and also a negligible amount of water vapor. The results present that dissolved carbon dioxide in water significantly enhances the heat transfer coefficient in compare to pure free convection regime. This is mainly due to the microscale mixing on the heat transfer surface, which is induced by bubble formation. In this investigation, experiments are performed at different bulk temperatures between 288 and 333 K and heat fluxes up to 400 kW $m^{-2}$ at atmospheric pressure. Bubble departure diameter, nucleation site density and heat transfer coefficient have been experimentally measured. A model has been proposed to predict the heat transfer coefficient.



## 1. Introduction

Free convection mechanism plays an important role in many industrial heat transfer processes. There are many developed correlations in the past few decades to predict the free convection heat transfer coefficients for different conditions, however, the effects of the dissolved gases, with negative solubility in liquids have never been considered. Generally, the homogeneous gas/liquid solutions can be classified in two different groups: (1) positive soluble and (2) negative soluble systems, i.e. the slope of solubility saturation curve relative to temperature are positive for the positive soluble and negative for the negative soluble solutions. Carbon dioxide/water solution is a negative soluble system; accordingly, any heating surface which is exposed to this solution would locally release a fraction of dissolved gas, which is exceeding the saturation level of the gas in liquid. The released gas forms bubbles, analogous to boiling phenomenon, however with different mechanisms. In the boiling phenomenon, the bubbles absorb the latent heat of vaporization, in contrast, in the mentioned system, bubbles absorb the heat of solution. In both cases, the heat transfer coefficient is highly enhanced in compare to pure convection heat transfer. This enhancement is mainly related to the intense micro-convection; the result of bubble formation and local movements of liquid around the heating surface. Fig. 1 presents the solubility function of carbon dioxide in water versus temperature [1]. Carbonic acid has many industrial applications such as soda pop, as a gas in the medical field, pharmaceutical, cosmetics, oil shale, food processing aid, medical, anesthetic, fuel, industrial, lasers, bottling, contact lens cleaner, engines, hydrolysis of starch, drugs, and welding. The phase-change heat transfer coefficients and pressure loss factors required for the design of boilers and evaporators involve some of the most complex thermo-fluid phenomena.

In this investigation, saturated carbon dioxide/water solution has been selected as a negative soluble gas/liquid system and a horizontal rod heater is used as the heating surface. This phenomenon has close interaction to bubble dynamics and convection heat transfer. A brief literature review is accordingly presented.

## 2. Literature review

### 2.1. Bubble departure diameter

Bubble departure diameter is known as a key parameter in many phenomena including boiling, bubble column systems, etc. The detailed impact of physical properties such as interfacial tension, heat of evaporation, viscosity and thermal conductivity on the bubble departure diameter are still not well understood. There are many proposed correlations for predicting the bubble departure diameter in boiling phenomenon. The Fritz [2] model is one

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