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Experimental and numerical study of mixed convection heat and mass transfer in a vertical channel with film evaporation

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ABSTRACT

The objective of the present study is to investigate experimentally the effect of film evaporation on mixed convective heat and mass transfer in a vertical rectangular channel. Two parallel channel walls are wetted by a water film and heated by a constant heat flux, while the other walls are dry and thermally insulated. The liquid film temperature, the evaporated flow rate, the upward airflow temperature and humidity are measured. Wide ranges of inlet airflow velocity, heat flux and liquid film flow rate are considered. Cases of laminar and turbulent airflow are considered. The experimental results show that evaporation takes place on the majority of the surface of the two walls and, in some cases, evaporative cooling occurs especially for small heating flux and large air velocities. Moreover, a numerical study is carried out in the case of a laminar flow and its results are compared to experimental ones. These comparisons lead to a good agreement with respect to liquid film and airflow temperatures in addition to the evaporated flow rate.

1. Introduction

This study of a particular humidification–dehumidification desalination system is a part of a number of different studies performed in our research group in order to improve desalination processes [3–5]. It consists of an air humidifier and water vapor condenser. It was established in the literature that this process is suitable for small capacity production plants. It offers several attractive features including operation at low temperature, ability to use sustainable energy sources (e.g. solar and geothermal energy), and requirements of low technology level [6]. Several studies [3,4,7] have shown that the production rate of distilled water is increased by increasing hot water temperature. Moreover, the production rate of distilled water exhibits a maximum by increase of the air and water flow rates. Therefore, it is clear that the design of the air humidifier is one of the keystones of the humidification–dehumidification system. The present study aims to better understand transfer mechanisms, which will result in a design that improves heat and mass transfer coefficients in the air humidifier.

One air humidifier configuration in use is a rectangular channel with water film falling along its internal walls [7]. Fundamental studies on combined heat and mass transfer in channels are abundant [8,9]. Many conditions are considered, such as symmetrically or asymmetrically heated channel, isothermal channel. These studies are experimental or numerical [4,5,8–11]. The following is a summary of some of the literature studies. Agunaoun [12,13] studied numerically film evaporation in a stream of humid air of a liquid film falling on an inclined plane heated at a constant temperature. They considered forced [12] or mixed convection [13] of humid air with several liquid mixtures. A boundary layer type model was adopted. The liquid film–gas interface has approximately the same temperature as the plate in the case of forced convection. In the case of mixed convection, the most important accumulated evaporation rate was obtained for ethylene glycol–water mixture.

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