Experimental Thermal and Fluid Science 35 (2011) 1383–1391

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Experimental investigation of convective heat transfer enhancement from 3D-shape heat sources by EHD actuator in duct flow

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ARTICLE INFO

Article history:
Received 25 October 2010
Received in revised form 19 April 2011
Accepted 21 May 2011
Available online 27 May 2011

Keywords:
Heat transfer enhancement
Duct flow
3D-shape ribs
Electrohydrodynamic (EHD)
Corona wind

ABSTRACT

Heat transfer enhancement from cylindrical heat sources as electronic components established at the bottom of duct with in-line arrangement and also from the bottom by electrohydrodynamic (EHD) actuator has been investigated experimentally. Air flow is drawn to the duct with various Reynolds numbers based on hydraulic diameter of inlet of the test section (Re = 0, 500, 1100, 2500 and 3870) that include natural convection (confined and unconfined cases) and forced convection (laminar and turbulent flows). Wire electrodes are arranged in transverse direction and perpendicular to the main flow with two various arrangements and high voltages are applied up to 30 kV in the wires. The results revealed that the second electrode arrangement (three wires over the ribs) is more effective due to more enhancement of heat transfer and less corona power consumption in comparison with the first one (four wires between the ribs). Also the electric field is obviously more effective for low Reynolds numbers.

1. Introduction

The heat generated by electronic components still requires more efficient cooling methods in order to maintain the equipments temperature at an acceptable level. Long life and reliable performance of a component may be attained by effectively controlling the device operating temperature by using a high voltage electric field. Under an intense electric field, air partially breaks down and is ionized and results in corona discharge. A significant aspect of corona discharge is the generation of corona wind. This phenomenon is caused by the ionization of air molecules and formation of electrons that accelerate in strong electric fields and collide with neutral molecules which results in more ionization. The ions are heavier than electrons; they accelerate and drag the neighboring air molecules. This results in formation of a secondary flow, known as corona wind that helps to increase convective heat transfer rate.

Many studies have been concluded to investigate convective heat transfer properties from heat sources in duct flow without applying electric field that make a good viewpoint for convective heat transfer in duct flows. A multi-faceted experimental investigation was carried out by Sparrow et al. [1] to study heat transfer and pressure drop for air flow in arrays of heat generating rectangular modules developed along one wall of a flat rectangular duct. In this study the effects of removing a module on heat transfer properties of other modules and also fully developed condition in the presence of modules have been studied. Hacohen et al. [2] investigated an experimental and theoretical study for both forced and free convection with both flush-mounted and protruding heat sources and compared them with each other. Mixed convection heat transfer from arrays of discrete flush-mounted heat sources that subjected to uniform heat flux and put in lower and upper surfaces of a horizontal channel was investigated experimentally by Dogan et al. [3]. From this experimental study, row-average surface temperature and Nusselt number distributions of the discrete heat sources were obtained. The results revealed that top and bottom heater surface temperatures increase with increasing Grashof number. Mohamed [4] experimentally investigated air cooling characteristics of an electronic devices heat sink with various square modules array and estimated the average heat transfer coefficient between the following air and modules array outer surfaces. The concluding results indicated that the average heat transfer little increased with increasing the following air velocities and the increasing of module to channel height ratio seemed to increase the average heat transfer coefficient.

A large number of papers on the electrohydrodynamic enhancement of heat transfer have been published in open literature. Some of them are presented here briefly. Owsenek and Seyyed-Yagoobi [5] experimentally investigated the corona wind enhancement of free convection using a heated horizontal flat plate with high voltage supplied to a needle suspended above heated plate. EHD enhanced heat transfer of natural convection inside an enclosure was investigated by Kasayapanand [6] in which the results revealed that heat transfer decreases with the Rayleigh number. Huang and Lai [7] investigated effects of Joule heating on EHD-enhanced natural

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doi:10.1016/j.expthermflusci.2011.05.006