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Numerical study of the evaporation of a liquid film with a low nanoparticles volume fraction

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Abstract

In this present work, a numerical study of conjugated heat and mass transfers along a vertical channel was performed. The effect of nanoparticles introduced in a liquid film flow (nanofluid) is investigated. The left plate of channel is heated by a constant heat flux, while the right wall is dry and insulated. The numerical method applied solves the coupled governing equations together with the boundary and interface conditions. Results are presented for nanofluid-air systems. Parametric computations are performed to evaluate the nanofluids performances with variant nanoparticles types and volume fraction.

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Keywords: nanofluids, liquid film, evaporation, nanoparticles

1. Introduction

Simultaneous heat and mass transfer between a thin liquid film and gas/vapour stream are widely encountered in many technological and industrial applications like desalination, air conditioning, cooling systems.... At this stage, evaporation process has a great impact on performance and energy efficiency. So far, many studies have been realized. Feddaoui et al. [1] investigate turbulent mixed convection heat and mass transfer in falling film of water inside a vertical heated tube, in order to analyse the combined buoyancy effects of thermal and mass diffusion on the tube flows. Recently, a new way to improve heat transfer of liquids is implemented. The fast advances in nanotechnology allowed the creation of a new generation of coolant called “nanofluids”. Many works have shown that nanofluids have higher thermal conductivities and higher convective heat transfer coefficients than conventional pure fluids [2,3]. Thus, studies of liquid films based on nanofluids still need to be addressed.

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This article presents a numerical investigation of the nanoparticles impact on evaporation process. Different types of nanoparticles are compared to the base fluid (water). The change of nanofluid volume fraction due to the evaporation is considered in this study.

Nomenclature

Cp	Specific heat $J.kg^{-1}.K^{-1}$	Greek symbols	
D	Mass diffusivity $m^2.s^{-1}$	δ_x	Local liquid film thickness m
h_{fg}	Latent heat of vaporisation J/kg	Γ_0	Inlet liquid mass flow rate $kg.s^{-1}.m^{-1}$
$\dot{m}$	Evaporation mass flux $kg.s^{-1}m^{-2}$	ϕ	Volume fraction of nanoparticles
Mr	Mass evaporation rate $\int_0^x \dot{m}.dx/\Gamma_0$		
Q_S	Sensible heat flux $W.m^{-2}$	Subscripts	
Q_T	Total heat flux $W.m^{-2}$	g	Gas
Q_W	Wall heat flux $W.\ m^{-2}$	nf	Nanofluid
X	Axial dimensionless coordinate 2x/(b.Re)	s	Solid particle
Y	Transversal dimensionless coordinate (y/b)	0	Inlet condition

2. Analysis

2.1. Physical model and assumption

Figure 1 shows the geometry of the physical problem in coordinates system. The right wall of the channel is thermally insulated while the other is wetted by liquid film, and heated by a constant heat flux. The vertical channel width and height are b and L respectively. The film is a water-based nanofluid liquid, containing different nanoparticles: Al_2O_3, and Ag. We consider that nanofluids used in this investigation are Newtonian and incompressible. The flow is assumed laminar. In addition, it is assumed that the base fluid and the nanoparticles are in thermal equilibrium and no slip occurring between them. The thermo-physical properties of the nanoparticles are listed in Table 1. The correlations used for water and gas-vapour mixture are extracted from [4,5].

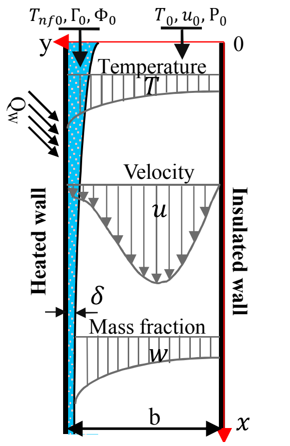

Fig. 1. Geometry of the problem

Table 1. Thermo-physical properties of used nanoparticles, Moumni et al. [6].