Chemical Engineering Science 174 (2017) 13–24

Contents lists available at ScienceDirect

Chemical Engineering Science

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

Natural convection heat transfer utilizing ionic nanofluids with temperature-dependent thermophysical properties

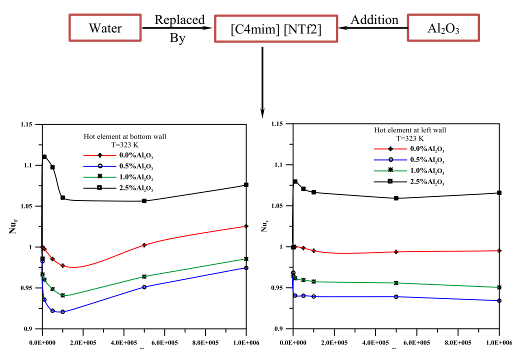
Alina-Adriana Minea [a,*], Wael M. El-Maghlany [b]

[a] Materials Science and Engineering Faculty, Technical University "Gheorghe Asachi" from Iasi, Romania
[b] Mechanical Engineering Department, Faculty of Engineering, Alexandria University, Egypt

HIGHLIGHTS

- Numerical evaluation of an ionic liquids nanofluid is proposed.
- A comparison with an alumina nanofluid in terms of Nu is inserted.
- New Nu correlation for IoNanofluids were developed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 June 2017
Received in revised form 25 August 2017
Accepted 30 August 2017
Available online 1 September 2017

Keywords:
Natural convection
Ionic liquid nanofluids
Thermophysical properties
Rayleigh number

ABSTRACT

Ionic liquid based nanofluids are a very new and novel class of fluids used for heat transfer. The thermophysical properties of these new fluids are extremely encouraging in comparison to base ionic liquids and recommend these new fluids for solar applications. This paper deals with a numerical implementation of an ionic liquid nanofluid in a square enclosure considering two heating situations; bottom heating and lateral heating of the enclosure. Comparison with a regular alumina nanofluid in terms of Nusselt number is inserted. Thermophysical properties of these Ionic liquid based nanofluids were considered variable with temperature and the numerical results are correlated as a function of *Ra* and volume concentration (ϕ) for the two studied cases in the range of $10^4 \le Ra \le 10^6$ and $0\% \le \phi \le 2.5\%$. As an overall conclusion, this innovative class of heat transfer fluids reveals great potential in advanced heat transfer applications.

1. Introduction

Novel heat transfer fluids with a high thermal stability are desirable for both high temperature direct solar collectors and concentrated solar collector as well as for other important heat transfer applications. Recently, in the open literature can be found a lot of studies that considered nanoparticles suspended in various liquids in order to increase the heat transfer capability of common fluids (Wilhelm and Letcher, 2014; Tan, 2011; Paul, 2014; Paul et al., 2015; Patankar, 1980; El-Maghlany et al., in press, 2014; El-Maghlany and Elazm, 2016; Teamah and El-Maghlany, 2010; Teamah et al., 2013; Aminossadati and Ghasemi, 2011; Liu et al., 2015). Most studied base fluids are water and ethylene glycol and the resulting new heat transfer fluids are usually called "nanofluids".

On the other hand, ionic liquids, composed of organic cations and organic or inorganic anions (Rogers and Seddon, 2003), have been demonstrated to have a wide range of new applications, especially were common heat transfer fluids cannot be considered

* Corresponding author.
E-mail addresses: aminea@tuiasi.ro (A.-A. Minea), elmaghlany@alexu.edu.eg (W.M. El-Maghlany).

http://dx.doi.org/10.1016/j.ces.2017.08.028
0009-2509/

Nomenclature

c_p	specific heat, J/kg K
g	acceleration of gravity, m/s^2
k	fluid thermal conductivity, W/m K
L	cavity width, m
Nu	average Nusselt number
Nu_L	local Nusselt number
p	pressure, N/m^2
P	dimensionless pressure
Pr	Prandtl number
Ra	Rayleigh number
T	local temperature, K
T_{av}	average temperature, K
T_c	cold wall temperature, K
T_h	hot wall temperature, K
ΔT	temperature difference, K
u	velocity components in x direction
v	velocity components in y direction
U	dimensionless velocity component in X direction
V	dimensionless velocity component in Y direction
w	the hot element length, m
x, y	dimensional coordinates
X, Y	dimensionless coordinates

Greek symbols

α	thermal diffusivity, m^2/s
β	coefficient of thermal expansion, K^{-1}
θ	dimensionless temperature
μ	dynamic viscosity, kg/m s
ν	kinematics viscosity, m^2/s
ρ	local density, kg/m^3
ϕ	volume concentration

Subscript

correlated	refers to the points given by the correlation
data	refers to the points obtained from numerical analysis
f	base fluid
ionf	IoNanofluids
nf	nanofluids based on water and alumina
r	ratio

(Welton, 1999). Their remarkable properties indicate that ionic liquids are the best candidates of heat transfer fluids in concentrated solar thermal systems (Liu et al., 2015; Rogers and Seddon, 2003; Welton, 1999; Fredlake et al., 2004; Aparicio et al., 2010). Plus, the thermophysical properties of ionic liquids have been broadly reported in the open literature (Fredlake et al., 2004; Aparicio

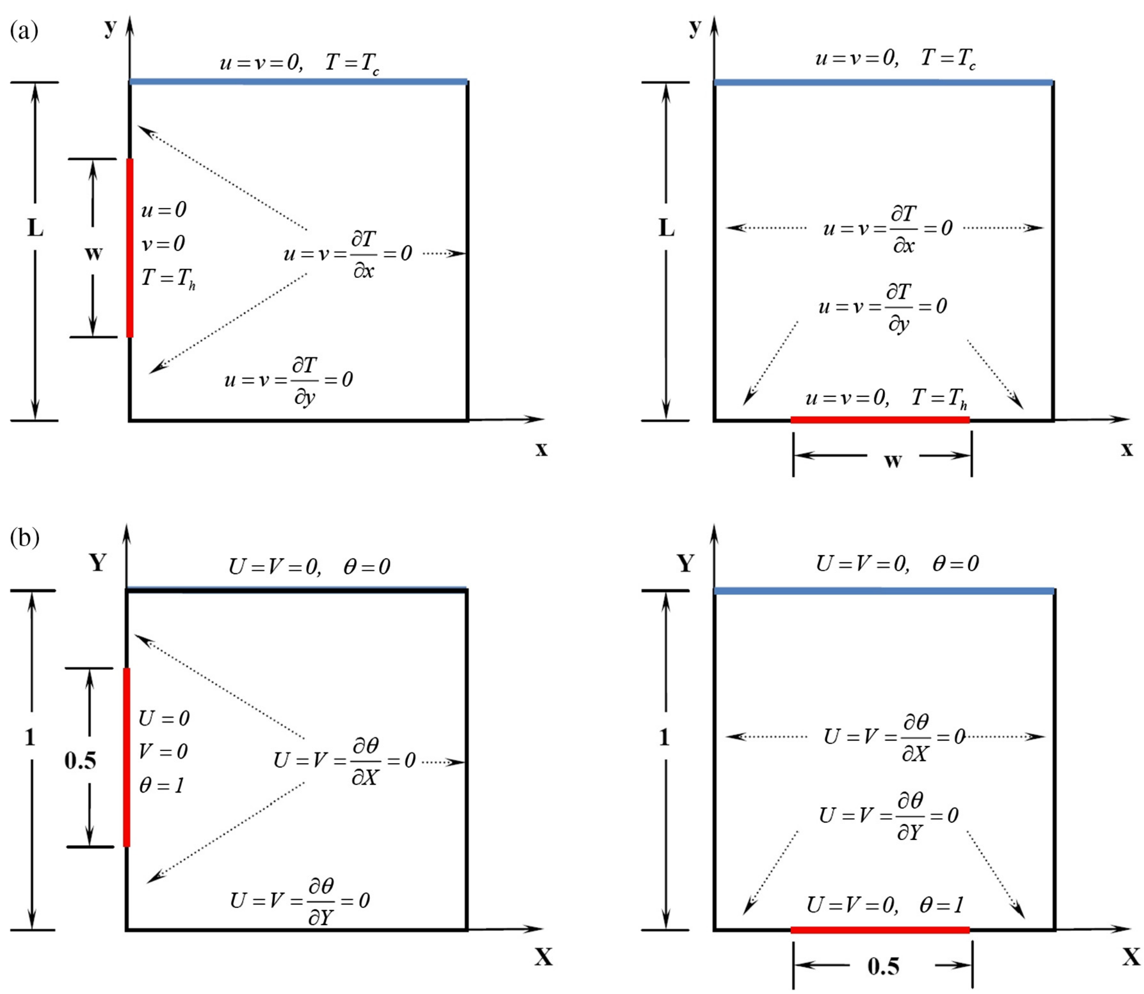


Fig. 1. A schematic diagram of the problem showing coordinates orientation and boundary conditions in dimensional (a) and dimensionless forms (b).