Advanced Powder Technology 27 (2016) 436–441

Contents lists available at ScienceDirect

Advanced Powder Technology

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

Original Research Paper

A comparative theoretical study on Al_2O_3 and γ-Al_2O_3 nanoparticles with different base fluids over a stretching sheet

N. Vishnu Ganesh [a], A.K. Abdul Hakeem [a,*], B. Ganga [b]

[a] Department of Mathematics, Sri Ramakrishna Mission Vidyalaya, College of Arts and Science, Coimbatore 641 020, India
[b] Department of Mathematics, Providence College for Women, Coonoor 643 104, India

ARTICLE INFO

Article history:
Received 9 July 2015
Received in revised form 3 January 2016
Accepted 17 January 2016
Available online 3 February 2016

Keywords:
Alumina
Gamma alumina
Nanofluid
Stretching sheet
Shooting technique

ABSTRACT

Nanoparticles provide potentials in augmenting the performance of convective heat transfer. In view of this, the present investigation provides comparative analytical and numerical studies on alumina and γ-alumina nanoparticles with different base fluids over a stretching sheet. Ethylene glycol and water are considered as base fluids. Boundary layer flow of γ-alumina nanofluid over a stretching sheet is considered first time in this article. The viscosity and thermal conductivity models which are derived from experimental data (Maiga et al., 2004, 2005) used for γ-alumina nanofluids and Brinkman viscosity and Maxwell's thermal conductivity models are used for alumina nanofluids. Governing boundary layer equations are solved both analytically and numerically using confluent hypergeometric function and fourth order Runge–Kutta method with shooting technique respectively. The results obtained for the velocity profile, temperature profile, skin friction coefficient and reduced Nusselt number are presented through plots. It is predicted that the same nanoparticles have different behavior on temperature profile with water and ethylene glycol.

1. Introduction

The performance of conventional heat transfer fluids such as water, minerals oil and ethylene glycol is often limited by their low thermal conductivities in many industrial areas including air-conditioning, chemical production, power generation, transportation and microelectronics. Suspensions of solid particles in conventional fluids improve the heat transfer characteristics of these fluids. There are many types of particles such as non metallic, metallic and polymeric. Using of macro-sized suspensions, industries will face some problems such as erosion of heat transfer, clogging of flow channels due to poor suspension stability, and increasing in pressure drop. Modern material science technology helps us to produce nano meter sized particles that their thermal and mechanical properties are different from those of the parent materials.

Suspensions of nanometer-sized particles in conventional heat transfer fluid are called Nanofluids [1] which are suitable for engineering applications and show several potential advantages such as better stability, dramatically high thermal conductivity and no extra pressure drop compared to other suspensions. Due to the exclusive features of nanofluids, many researchers have been motivated to investigate the heat transfer performance and flow characteristics of various nanofluids with different nanoparticles and base fluid materials [2–14]. Alumina nanofluids have attracted the research community because of its applications in many cooling processes [15–21]. Alumina nanoparticles are classified according to their size as alpha alumina and gamma alumina, etc. Surface properties of well-characterized samples of eta and gamma alumina were studied in [22].

In many industrial processes such as cooling of metallic sheets, crystal growing, in a cooling bath, manufacture and drawing of plastics and rubber sheets, glass–fiber and paper production, metal and polymer extrusion processes, the problem of flow and heat transfer induced by a stretched surface is very important. The rate of cooling plays an important role about the quality of the final product obtained from these processes, in which a moving surface emerges from a slit, and as a consequence, a boundary layer flow is appeared in the direction of the movement of the surface. The boundary layer flow of nanofluids over a stretching surface has been considered by many researchers in recent years [23–37] with various metal and oxide nanoparticles except gamma alumina nanofluids.

Keeping this in mind, in the present investigation we performed a comparative study on the boundary layer flow of alumina and

* Corresponding author.
E-mail address: abdulhakeem6@gmail.com (A.K. Abdul Hakeem).

http://dx.doi.org/10.1016/j.apt.2016.01.015
0921-8831/

Nomenclature

T	local temperature of the fluid	x, y	coordinates along and perpendicular to the sheet
T_∞	temperature far away from the sheet	ϕ	the solid volume fraction
Pr	Prandtl number	ρ_{nf}	the effective density of the nanofluid
$Re_x^{1/2}C_f$	reduced skin friction coefficient	ρ_f	density of the pure fluid
$Re_x^{-1/2}Nu_x$	reduced Nusselt number	ρ_s	density of the nanoparticles
k_{nf}	thermal conductivity of the nanofluid	μ_{nf}	effective dynamic viscosity of the nanofluid
k_f	thermal conductivity of the base fluid	μ_f	dynamic viscosity of the basic fluid
k_s	thermal conductivity of the nanoparticles	η	space variable
u, v	velocity component in x and y direction		

gamma alumina nanofluids over a stretching sheet with water and ethylene glycol as base fluids. The viscosity and thermal conductivity models which are derived from experimental data [15,17] used for γ-alumina nanofluids and Brinkman viscosity and Maxwell's thermal conductivity models are used for alumina nanofluids. Both analytical and numerical investigations are carried out. The mathematical formulation of problem is given in the next section.

2. Formulation of the problem

Consider a steady two-dimensional laminar boundary layer flow of an incompressible alumina and gamma alumina nanofluids over a stretching sheet with different base fluids such as water and ethylene glycol (see Fig. 1). The nanofluid flow is generated, due to the stretching of the sheet, caused by two equal and opposite forces along the x-axis. The velocity of the stretching sheet is $u_w = ax$ and the temperature at the stretching surface is $T_w = T_\infty + bx^2$. Where a and b are constants and T_∞ is the ambient temperature. It is also assumed that the base fluids and the nanoparticles are in thermal equilibrium and no slip occurs between them. The thermo physical properties of the nanofluids are considered as in Table 1. Taking the above assumptions into consideration, the steady boundary layer equations governing the convective flow and heat transfer for a nanofluid can be written as

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{\mu_{nf}}{\rho_{nf}}\frac{\partial^2 u}{\partial y^2}, \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{k_{nf}}{(\rho C_p)_{nf}}\frac{\partial^2 T}{\partial y^2}. \tag{3}$$

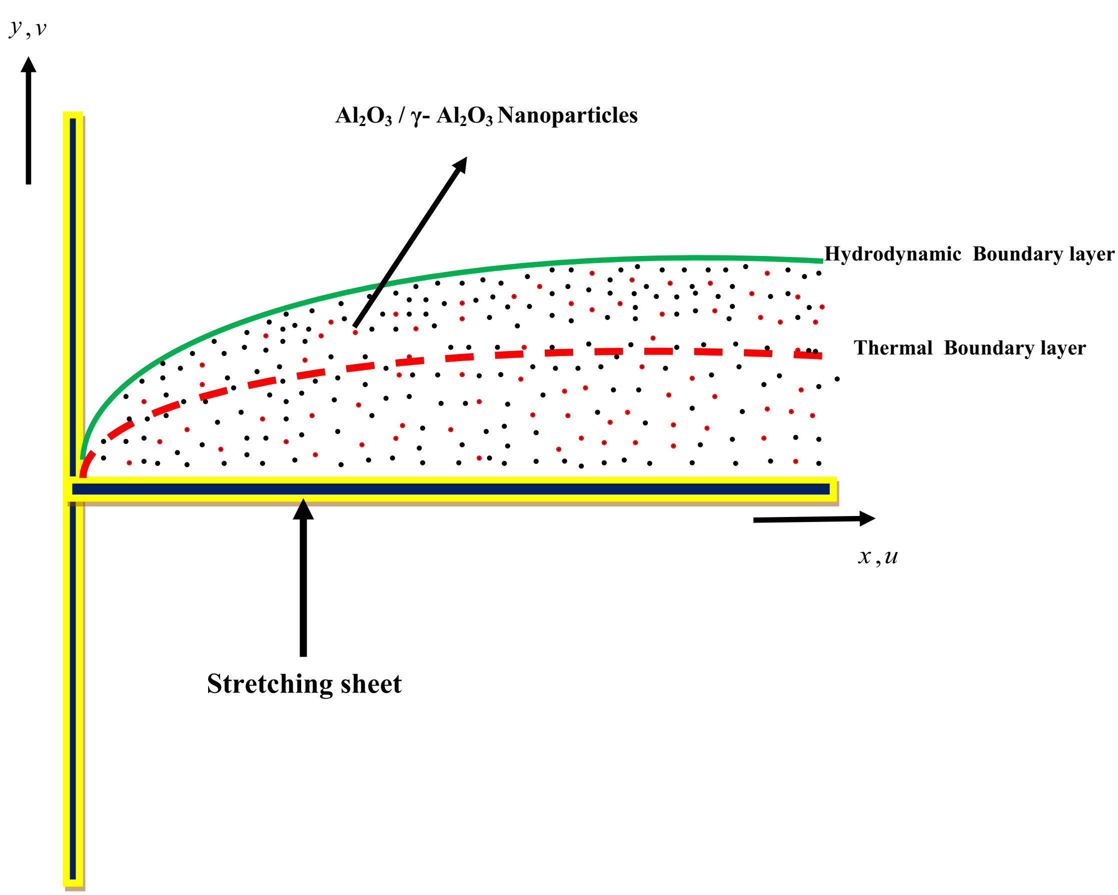

Fig. 1. Physical model and coordinate system of the problem.