EXACT SOLUTIONS ON UNSTEADY CONVECTIVE FLOW OF VISCOUS, CASSON, SECOND GRADE AND MAXWELL NANOFLUIDS

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I hereby declare that the work in this thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
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TO MY BELOVED FAMILY ESPECIALLY MY LATE PARENTS, SIBLINGS AND BROTHER IN LAW

THANK YOU FOR EVERYTHING

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Sidra Aman

ABSTRAK

Aliran pemindahan haba dan jisim bagi bendalir Newtonan dan tak-Newtonan disebabkan oleh olakan mempunyai banyak kegunaan yang penting, seperti di dalam industri, kimia, kosmetik, farmasi dan kejuruteraan. Dalam tesis ini, aliran olakan tak mantap dengan pelbagai bendalir Newtonan tak-Newtonan dan bendalir hybrid nano tak Newtonan seperti hibrid Casson, gred kedua dan bendalir nano Maxwell dalam saluran menegak atau melepasi plat menegak dikaji. Tiub nano karbon, zarah nano graphene, kobalt, tembaga dan alumina telah digunakan untuk meningkatkan kadar pemindahan haba bendalir di dalam kerja penyelidikan ini. Bendalir nano mempunyai pelbagai kegunaan dalam automotif seperti bahan penyejuk, mikroelektronik, mikrocip dalam komputer, sel bahan api dan bioperubatan. Permasalahan aliran olakan bebas dan bendalir nano campuran dikaji dalam media berliang dan tak berliang, dengan/tanpa pengaruh magnetohidrodinamik (MHD). Syarat-syarat yang lain seperti plat menegak berayun, kesan radiasi dan penjanaan haba dipertimbangkan. Idea derivatif pecahan masa Caputo telah digunakan dalam beberapa permasalahan adalah topik yang novel pada masa kini. Kelebihan derivatif pecahan adalah julat peningkatan derivatif dalam kes ini dan derivatif pembolehubah telah digunakan untuk julat nombor. Pembolehubah tak berdimensi digunakan untuk menurunkan persamaan menakluk berdimensi bersama dengan syarat awal dan syarat sempadan kepada bentuk tak berdimensi. Penyelesaian tepat untuk halaju, suhu dan kepekatan diperoleh dengan menggunakan teknik jelmaan Laplace, dan beberapa permasalahan diselesaikan dengan menggunakan teknik pertubasi bersama dengan jelmaan Laplace songsang, seperti teknik Zakian. Ungkapan sepadan untuk geseran kulit, nombor Nusselt dan nombor Sherwood juga dihitung. Hasil dapatan diplot menggunakan perisian MathCAD-15 dengan sifat termofizik zarah nano dan bendalir asas. Keputusan bergrafik membincangkan dengan terperinci kesan pelbagai parameter seperti radiasi, nombor Peclet, nombor Grashof, parameter pecahan dan pecahan isipadu zarah nano. Melalui objektif kajian didapati halaju bendalir nano meningkat dengan peningkatan nombor haba/larutan nombor Grashof, parameter radiasi sementara berkurangan dengan pecahan isipadu zarah nano. Profil suhu meningkat dengan parameter radiasi, penjanaan haba dan pecahan isipadu. Kekonduksian termal dan nombor Nusselt bendalir nano memaparkan peningkatan yang ketara dengan peningkatan pecahan isipadu.

ABSTRACT

The heat and mass transfer flow of Newtonian and non-Newtonian nanofluids caused by convection has much practical significance, such as in industries, chemicals, cosmetics, pharmaceuticals and engineering. In this thesis, the unsteady convection flows of Newtonian, non-Newtonian and non-Newtonian hybrid nanofluids such as Casson hybrid, second grade and Maxwell nanofluids in a vertical channel or past a vertical plate will be studied. Carbon nanotubes (CNTs), graphene, cobalt, copper and alumina nanoparticles are used for the enhancement of heat transfer rate of fluids in this research work. Nanofluids have a range of applications in automobiles as coolants, microelectronics, microchips in computer, fuel cells and biomedicine. The problem of free and mixed convection flow of nanofluids is studied in a porous as well as non-porous media, with or without magnetohydrodynamics (MHD) influence. Other conditions like oscillating vertical plate, radiation effect and heat generation have been considered. The idea of Caputo time fractional derivative is used in some problems which is a novel topic nowadays. The advantage of fractional derivative is that the range of derivative increases in this case and the derivative of variable are used for a range of numbers. Appropriate non-dimensional variables are used to reduce the dimensional governing equations along with imposed initial and boundary conditions into dimensionless forms. The exact solutions for velocity, temperature and concentration are acquired via Laplace Transform technique and, in some places, regular perturbation technique along with inverse Laplace transform i.e. Zakian technique. The corresponding expressions for skin friction, Nusselt number and Sherwood's number have been calculated. The outcomes acquired are plotted via computational software MathCAD-15 using the specific thermophysical properties of nanoparticles and base fluids. The graphical outcomes have been discussed to delineate the impact of various embedded parameters such as radiation parameter, Peclet number, Grashof number, fractional parameter and volume fraction of nanoparticles. Throughout the objectives, velocity of the nanofluid is found to be increasing with increasing thermal/solutal Grashof number, radiation parameter while decreasing with volume fraction of nanoparticles. Temperature profile increases with radiation parameter, heat generation and volume fraction. Thermal conductivity and Nusselt number of the nanofluids exhibit significant increment with increasing volume fraction.

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$\mathbf{A}_1, \mathbf{A}_2$	Rivlin-Ericksen tensors
Al_2O_3	Alumina
Ag	Silver
b	Body force per unit mass vector
$\underline{\mathbf{b}}$	Induced magnetic field
B_0	Magnitude of magnetic field
Br	Brinkman number
CuO	Copper oxide
Cu	Copper
C_0	Concentration on the left wall
C_d	Concentration on the right wall
Cf	Skin friction
C_∞	Ambient concentration
$\mathbf{D}$	Rate of strain
D_m	Mass diffusion
$\boldsymbol{e}_{ij}$	$(i, j) - th$ component of the deformation rate
$\mathbf{E}$	Electric field
$\mathbf{g}$	Gravitational acceleration
Gm	Solutal Grashof number
Gr	Grashof number
h_f	Heat flux
$\mathbf{I}$	Unit vector
J	Current density
k_1	Variable permeability,
M	Magnetic parameter
N	Radiation parameter
Nu	Nusselt number

p	Pressure
Pe	Peclet number
p_h	Hydrostatic pressure
p_d	Dynamic pressure
p_y	Yield stress of the fluid
q	Laplace transform parameter
$\mathbf{q}"$	Heat flux
q_x, q_y, q_z	Heat fluxes in x, y, z directions
Q	Total Heat
r	Real number
Re	Reynolds number
$\mathbf{S}$	Extra stress tensor
Sc	Schmidt number
Sh	Sherwood number
t	Time
$\mathbf{T}$	Cauchy stress tensor
T	Temperature of the fluid
T_0	Temperature on the left wall
T_d	Temperature on the left wall
T_∞	Ambient temperature
TiO_2	Titanium oxide formula
u,v,w	Velocity components in x, y and z direction
U	Internal energy
$\mathbf{V}$	Velocity vector field
V_w	Suction/Injection parameter
W	Work done
x, y, z	Cartesian coordinates

Greek Letters

α	Fractional parameter
α_0	Mean radiation absorption coefficient
α_1, α_2	Normal stress moduli
α_s	Second grade fluid parameter
β	Casson fluid parameter
β_C	Volumetric solutal expansion coefficient
β_{CNT}	Volumetric coefficient of thermal expansion of CNTs
β_T	Volumetric thermal expansion coefficient
β_f	Volumetric coefficient of thermal expansion of base fluid
β_{nf}	Volumetric coefficient of thermal expansion of nanofluid
ρ_{nf}	Density of nanofluid
ρ	Fluid density
ρ_∞	Density of the ambient fluid
ρ_0	Density of ambient fluid
$(\rho\beta)_{nf}$	Thermal expansion coefficient of nanofluid
$(\rho c_p)_{nf}$	Specific heat capacitance of nanofluid
τ	Dimensionless shear stress
μ	Dynamic viscosity
ν	Kinematic viscosity
μ_B	Plastic dynamic viscosity of non-Newtonian fluid
μ_{nf}	Viscosity of the nanofluid
σ	Electrical conductivity of fluid
σ_{nf}	Electrical conductivity of nanofluid
ω	Frequency of the pressure gradient.
λ	Relaxation time
λ_s	Steady part of amplitude

λ_p	Pulsating part of amplitude
π_1	Product of component of deformation rate with itself
π_c	Critical value of the product of component of deformation rate with itself
k_i, γ_i	Constants for Zakian technique
ϕ	Volume fraction of nanoparticles
ϕ_1	Volume fraction of copper nanoparticles
ϕ_2	Volume fraction of Alumina nanoparticles
φ	Porosity of porous medium
∇	Vector operator

SUBSCRIPTS

∞	Ambient condition
$*$	Dimensional
f	Fluid
nf	Base fluid
nf	Nanofluid
$hbnf$	Hybrid nanofluid
$s1$	Copper nanoparticles
$s2$	Alumina nanoparticles
w	Condition on the wall

LIST OF ABBREVIATION

CNTs	Carbon Nanotubes
KKL	Koo-Kleinstreuer-Li
MathCAD	Mathematical Computer-Aided Design
MHD	Magneto Hydrodynamic
MWCNTs	Multiple Walls Carbon Nanotubes
PDE	Partial Differential Equations
ODE	Ordinary Differential Equations
PPF	Pulsatile Poiseuille Flow
SWCNTs	Single Walls Carbon Nanotubes

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