STEADY FORCED CONVECTION FLOW AND HEAT TRANSFER IN A NANOFLUID WITH PASSIVE CONTROL MODEL

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MASTER OF SCIENCE

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and, in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations 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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ABSTRAK

Kajian mengenai aliran bendalir dan pemindahan haba secara olakan mempunyai aplikasi yang penting dalam proses kejuruteraan dan industri contohnya ia digunakan dalam proses penyejukan enjin kenderaan. Bendalir seperti air selalu digunakan sebagai bendalir pemindah haba disebabkan oleh kapasiti habanya yang tinggi. Namun begitu, air mempunyai kekonduksian terma yang rendah dan seterusnya memberi kesan terhadap proses pemindahan haba. Oleh itu, sejenis bendalir yang mempunyai ampaian zarah pepejal ke dalam bendalir asas iaitu nanobendalir telah dipertimbangkan disebabkan oleh sifat bendalir zarah yang mampu meningkatkan pemindahan haba. Model matematik bagi nanobendalir kebiasaannya menggunakan syarat sempadan yang mengandaikan pecahan isipadu nanozarah di permukaan adalah tetap. Walau bagaimanapun, syarat sempadan ini mungkin tidak mampu menerangkan dengan jelas bagi pecahan isipadu nanozarah di sempadan. Disebabkan itu, syarat sempadan berbeza yang telah dipertimbangkan dalam tesis ini di mana fluks jisim nanozarah di sempadan sebagai sifar dan diselaraskan dengan sewajarnya telah digunakan dalam tesis ini. Selain itu, penggunaan bendalir mikrokutub sebagai bendalir asas bagi nanobendalir telah diaplikasikan dalam banyak kajian. Kesan setempat yang terjadi disebabkan gerakan intrinsik dan struktur mikro bagi elemen bendalir yang penting bagi model ini boleh memberi kelebihan dalam menerangkan jenis – jenis bendalir seperti ampaian polimer dan darah haiwan. Oleh kerana itu, tiga analisis berangka aliran nanobendalir dan mikrokutub nano dengan kesan dan geometri berbeza telah dibincangkan dalam tesis ini. Kesan tersebuat adalah pelesapan likat, *Soret* dan *Dufour* dan tindakbalas kimia manakala geometri dalam kajian ini adalah permukaan rata bergerak, lembaran peregangan dan baji. Bagi membina model permasalahan ini, siri pemboleh ubah transformasi yang digunakan untuk mengubah persamaan menakluk berdimensi menjadi persamaan pembezaan tidak berdimensi. Persamaan tidak berdimensi yang merupakan persamaan pembezaan biasa kemudiannya diselesaikan secara berangka menggunakan kaedah *Runge-Kutta Fehlberg*. Keputusan yang diterima kemudian dibandingkan dengan kes terhad daripada kajian sebelumnya. Ini dilakukan bagi menentukan ketepatan keputusan yang dihasilkan. Beberapa parameter telah dianalisis dalam tesis ini iaitu nombor Eckert, nombor *Soret*, nombor *Dufour*, medan magnet, gerakan *Brown*, termoforesis, nombor *Lewis* dan nombor Prandtl. Keputusan bagi nombor Nusselt terturun, pekali geseran kulit, profil halaju, profil halaju bersudut, profil suhu dan profil kepekatan telah dibentangkan dalam jadual dan graf. Profil suhu dan kepekatan didapati menunjukkan keputusan yang tetap apabila kesan pelesapan likat dan tindakbalas kimia dikaji. Profil suhu meningkat apabila parameter termoforesis dinaikkan. Ketika terjadi termoforesis, zarah daripada kawasan yang panas akan di pindahkan ke kawasan yang sejuk. Ini menyebabkan suhu nanobendalir meningkat disebabkan jumlah nanozarah yang banyak dipindahkan daripada kawasan panas. Profil kepekatan didapati menaik dan menurun bagi kedua – dua masalah apabila parameter termoforesis dan gerakan *Brown* dinaikkan. Namun begitu, kewujudan *Soret* dan *Dufour* menjadikan profil suhu meningkat apabila gerakan *Brown* dinaikkan dan profil kepekatan menurun dan menaik apabila parameter termoforesis dinaikkan. Perbandingan yang dibuat dengan kajian lepas berdasarkan pecahan isipadu zarah yang malar menunjukkan pembezaan iaitu profil suhu didapati menaik apabila gerakan *Brown* dinaikkan dan profil kepekatan menaik apabila parameter termoforesis dinaikkan.

ABSTRACT

The study of convective heat transfer and fluid flow has important engineering and industrial applications, for instance in the cooling of engine vehicles. Fluid such as water is commonly used as a heat transfer fluid because of its high heat capacity. Nevertheless, the limitation of water and the low thermal conductivity of other conventional heat transfer fluids could affect the efficiency of heat exchange. Therefore, a type of fluid with suspension of solid particles into base fluid, namely nanofluid was considered due to the property of nanofluid that enhances heat transfer. Mathematical models of nanofluid normally include a boundary condition that assumed nanoparticle volume fraction at the surface is constant. This boundary condition however might not be able to describe adequately the condition of nanofluid volume fraction at the boundary. Hence, a different boundary condition that considers nanoparticle mass flux at the boundary to be zero and adjusted accordingly is applied in this thesis. Recently, the use of micropolar fluid as a base fluid to nanofluid was applied in many studies. The local influence of intrinsic motion and microstructure of the fluid elements that are essential to this model of fluid can be advantageous as it can appropriately describe the types of fluid such as polymeric suspension and animal blood. Motivated by these reasons, numerical analysis of nanofluid and micropolar nanofluid flow with zero nanoparticle mass flux along with three different effects and geometries for each problem were deliberated in this thesis. The effects are viscous dissipation, Soret and Dufour, and chemical reaction, and the geometry that was investigated are moving plate, stretching plate, and wedge. In order to reduce the governing equations, series of transformation variables are used to transform the dimensional governing equations into dimensionless differential equations. The non-dimensional equations in ordinary differential equations were then solved numerically using Runge-Kutta Fehlberg. The results obtained were then compared with the limiting cases from previous study. This is done to determine the accuracy of the results published. Several parameters were examined in this thesis, namely Eckert number, Soret number, Dufour number, magnetic field, Brownian motion, thermophoresis, Lewis number, and Prandtl number. The results of reduced Nusselt number, skin friction coefficient, velocity profile, angular velocity profile, temperature profile, and concentration profile for each parameter were presented in tables and graph. It was found that the temperature and concentration profile shown a consistent result when there is an effect of viscous dissipation and chemical reaction. Temperature profile increases when thermophoresis parameter increases. In thermophoresis, the particle from the heated region is transferred to the cold region. Thus, this causes the nanofluid temperature to be increasing due to huge number of nanoparticles shifted from the hot region, which enhance the fluid temperature. Concentration profile was found to increase then decrease for both of the problems when the thermophoresis parameter and Brownian motion parameter increase. However, in the presence of Soret and Dufour, the temperature profile was found to increase when Brownian motion parameter increases, and concentration decreases then increases when the thermophoresis parameter increases. In comparison to the previous study, the difference is the temperature profile increases following an increase of Brownian motion parameter and concentration profile increase when thermophoresis increases.

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