ABSTRACT

G-jitter characterizes a small fluctuating gravitational field brought about, among others by crew movements and machine vibrations aboard spacecrafts or in other low-gravity environments such as the drop-tower and parabolic flights. In this dissertation, Crank-Nicolson scheme is used to determine the numerical solution of the g-jitter induced free convection with constant heat flux. The governing equations are solved numerically using different values of Prandtl numbers. Results included are the variations of the skin friction, wall temperature, the velocity and temperature profiles.

ABSTRAK

Ketar-g mencirikan suatu ayunan kecil medan gravity yang terhasil antaranya oleh gerakan angkasawan dan getaran mesin di dalam kapal angkasa atau di persekitaran graviti rendah yang lain misalnya menara-jatuh dan penerbangan parabolik. Dalam disertasi ini, Crank-Nicolson akan digunakan untuk mendapatkan penyelesaian berangka bagi kesan ketar-g ke atas pemindahan haba di permukaan sfera. Persamaan-persamaan yang diterbitkan akan diselesaikan dengan menggunakan nilai Prandtl yang berlainan. Keputusan kajian turut digambarkan secara grafik untuk geseran kulit, suhu serta profil halaju dan suhu.

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LIST OF SYMBOLS / NOTATIONS

$\bar{a}$ - radius of a sphere

$g(t)$ - g-jitter or residual gravity field

g_0 - magnitude of g-jitter

Gr - Grashof number

$\mathbf{k}$ - unit vector pointing vertically upward

p - non-dimensional pressure

Pr - Prandtl number

q_w - wall heat flux

r - non-dimensional radial coordinate

Re - Reynolds number

t - time

T - non-dimensional fluid temperature

T_0 - mean temperature

U_c - characteristic velocity

u, v - velocity components along x and y axes

$\boldsymbol{\upsilon}$ - non-dimensional velocity vector

Greek symbols

β_T - thermal expansion coefficient

η - non-dimensional transformed independent variables

θ_a - polar angle

κ_c - thermal conductivity

μ - dynamic viscosity

υ - kinematic viscosity

ρ - density

ε - non-dimensional small quantity

ϕ - non-dimensional concentration

ψ - non-dimensional stream function

ω - frequency of g-jitter oscillation

Superscripts

$-$ - dimensional variables

$'$ - differentiation with respect to η

s - denotes steady part of the solution

u - denotes unsteady part of the solution

Subscripts

w - condition at the wall

∞ - ambient condition

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Gravity is identified by physicists as one of the four types of forces in the universe alongside the strong and weak nuclear forces as well as the electromagnetic force. Indeed, gravitational attraction is a fundamental property of matter that exists throughout the known universe [Rogers, Vogt, Wargo [1]].

Nevertheless, there are times when it is not advantageous for scientists to perform their researches under its full influence. Therefore, these scientists will conduct their experiments in microgravity environment. A microgravity environment is a condition in which the effects of gravity are greatly reduced where the apparent weight of a system is small compared to its actual weight due to gravity. The environment where astronauts float in the International Space Station is one of the many examples of microgravity environment.

Space experiments in accordance with microgravity have revealed unknown or nonexistent effects on Earth which can be harmful to certain experiments. One of these effects is g-jitter or residual accelerations phenomena associated with the microgravity environment. G-jitter is the inertia effects due to quasi-steady, oscillatory or transient accelerations arising from crew motions and machinery vibrations in parabolic aircrafts, space shuttles or other microgravity environments. G-jitter characterizes a small fluctuating gravitational field, very irregular in amplitude, random in direction and contains a broad spectrum of frequencies

(Schneider and Straub [2], Alexander et. al., [3] Nelson [4]). In an experiment supported by the NASA Office of Life and Microgravity Sciences and Applications, g-jitter dominates the spacecraft acceleration environment. It is comprised of a myriad frequencies and displays no preferred orientation. The g-jitter magnitudes can be as high as 1 milli-g (10^{-3} g) (Ramachandran and Baugher [5]).

For this study, we consider the buoyancy-driven laminar flow around a fixed sphere of radius $\bar{a}$ immersed in a viscous and incompressible Boussinesq fluid, which is at uniform temperature T_∞. It is also assumed that the sphere is subjected to a constant heat flux q_ω.

1.2 Significance of research

The effect of g-jitter on experiments, compared to ideal zero gravity conditions, is largely unknown, especially in quantitative terms. Some researchers have ventured into this foray, Shafie [6] and Amin [7], to name a few. Thus, it is of great interest to quantitatively assess acceptable accelerations for a given experiment.

As noted before, significant levels of g-jitter have been detected during space missions in which low-gravity experiments were being conducted. Even a relatively modest acceleration of 10^{-5} g_o can have a significant impact on solute segregation (Pan et al. [8]).

To understand fully the impact of g-jitter, scientists and researchers need to rely on modelling (Alexander et. al. [3]). Researchers may utilize theoretical models effectively to predict the experiment’s sensitivity to g-jitter, bearing in mind that the time-dependent nature of the g-jitter should be properly characterized beforehand (Alexander et. al. [9]). For materials science experiments conducted in low earth-orbit spacecraft, many questions are raised regarding experiment’s sensitivity to residual acceleration. It is essential to provide the answers for these questions so that the scientific return from such experiments is maximized. Shafie [6] and Amin [7] have strived to present the much needed answers through their respective research. Akin to the researches that preceded this particular study, the results of this study should be helpful in understanding the g-jitter effects on fluid mechanics process in microgravity conditions and better engineering design could be made in the future.

1.3 Objectives of the Study

The main objective of this study is to examine theoretically the effect of g-jitter on free convection problems. Specifically, to obtain the numerical computation for g-jitter induced free convection with constant heat flux.

1.4 Scope of the Study

The study is concerned with the generation of steady streaming due to g-jitter induced free convection from a sphere, which is subjected to a constant heat flux. For this study, the governing boundary layer equations are solved numerically using the Crank-Nicolson method.

1.5 Thesis Outline

This thesis consists of six chapters including this chapter.

In this chapter, which is the introductory chapter, we have presented the research background, objectives, scope and the significance of this research.

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