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entitled

PLASMA FLOW CONTROL

FOR NOISE REDUCTION

ON AIRCRAFT LANDING GEAR

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PLASMA FLOW CONTROL

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ON AIRCRAFT LANDING GEAR

A Prospectus for a Dissertation

Submitted to the Graduate School

of the University of Notre Dame

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

by

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PLASMA FLOW CONTROL

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Abstract

by

Michael C. Wicks

Please note that the full LaTeX source code (and an associated `Makefile`) is available from the University of Notre Dame Graduate Student Union web site. The Information Technology Committee page[1] has all the necessary files in download-able form. This particular dissertation was developed under Unix, but is also be usable under Windows with the appropriate LaTeX setup and was modified on a Windows system in 2012-2013. It should also work with on Mac.

While the source code for this document provides an excellent example for how to use the NDdiss2$_\varepsilon$ LaTeX class to write a Notre Dame thesis, it is *not* a substitution for the documentation of the NDdiss2$_\varepsilon$ LaTeX class (also available on the ND GSU web site).

In this thesis, I will tell all that I know about Gnus. Gnus are wonderful little creatures that inhabit the center of the earth and give us wonderful and plentiful trees, dirt, and other earthly-things.

In short, we should love and cherish the Gnus. They can be very friendly, and are often mistaken for squirrels on the University of Notre Dame campus. Feed them

[1]`http://www.gsu.nd.edu/`

whenever possible. If they get caught in trash cans, tip them over so that they can get out.

This abstract is going to continue on, including a few formulas, just for the sake of spilling over on to two pages so that we can see the author's name in the top right corner:

$$\begin{aligned} a^2 + b^2 &= c^2 \\ E &= mc^2 \\ \frac{e}{m} &= c^2 \\ a^2 + b^2 &= \frac{e}{m} \end{aligned}$$

These equations, by themselves mean nothing. But to the common Gnu, they define a whole way of living. While intricate mathematical implications certainly do not infiltrate the majority of humans' lives, every Gnu, from birth, is imbued with a sense of mathematical certainty and guidance. All Gnus, great and small, feel at one with mathematics. The cute furry bit is just a scam for their calculating minds.

To Laurimar

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CHAPTER 1

INTRODUCTION

Airframe noise is significant

Landing gear is primary source of airframe noise

Health risks

1.1 Motivation

The present work is motivated to reduce noise by flow control via application of DBD plasma actuator technology.

1.2 Theory of Aeroacoustics

The modern theory of aeroacoustics, that is sound generated by aerodynamic means, is based on James Lighthill's so-called acoustic analogy. He states that sound generated in a fluid flow is only important in regions of turbulent fluctuations [**?**]. Based on this assumption, the Navier-Stokes Equation and isentropic equation of state are

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u_i)}{\partial x_i} = 0 \tag{1.1}$$

$$\frac{\partial (\rho u_i)}{\partial t} + \frac{\partial (\rho u_i u_j + P_{ij})}{\partial x_j} = 0 \tag{1.2}$$

$$c_o^2 = \frac{\partial p}{\partial \rho}|_{s=const.} = \frac{p'}{\rho'}. \tag{1.3}$$

$$\frac{\partial^2 \rho}{\partial t^2} - c_o^2 \nabla^2 \rho = \frac{\partial^2 T_{ij}}{\partial x_i \partial x_j}. \tag{1.4}$$

$$T_{ij} = \rho u_i u_j + P_{ij} - c_o^2(\rho - \rho_0)\delta_{ij}, \tag{1.5}$$

where

$$\delta_{ij} = \left\{ \begin{array}{ccc} 1 & \text{if} & i = j \\ 0 & \text{if} & i \neq j \end{array} \right\} \tag{1.6}$$

$$T_{ij} \approxeq \rho_0 u_i u_j. \tag{1.7}$$

$$p' = c_o^2 \rho' = \frac{1}{4\pi} \frac{\partial^2}{\partial x_i \partial x_j} \int_V \frac{T_{ij}}{r} dV, \tag{1.8}$$

$$\int_V dV \propto D^3 \tag{1.9}$$

$$T_{ij} \propto \rho_o U_o^2 \tag{1.10}$$

$$\frac{\partial}{\partial x_i} = \frac{\partial}{c_o \partial t} \propto \frac{f}{c_o} \propto \frac{U_o}{c_o D} \tag{1.11}$$

$$p' \propto \left(\frac{U_o}{c_o D}\right)^2 \left(D^3\right) \left(\frac{\rho_o U_o^2}{r}\right) \propto \frac{U_o^4}{r} \tag{1.12}$$

$$W \propto p'^2 \propto \frac{U_o^8}{r^2} \tag{1.13}$$

$$p' = \underbrace{\frac{1}{4\pi}\frac{\partial^2}{\partial x_i \partial x_j}\int_V \left[\frac{T_{ij}}{r}\right] dV}_{I} - \underbrace{\frac{1}{4\pi}\frac{\partial}{\partial x_j}\int_S \left[\frac{P_{ij}+\rho v_i v_j}{r}\right] n_i dS}_{II} + \underbrace{\frac{1}{4\pi}\frac{\partial}{\partial t}\int_S \left[\frac{\rho v_i}{r}\right] n_i dS}_{III}, \tag{1.14}$$

$$II : \frac{1}{4\pi}\frac{\partial}{\partial x_j}\int_S \left[\frac{P_{ij}+\rho v_i v_j}{r}\right] n_i dS \propto \left(\frac{U_o}{c_o D}\right)\left(\frac{\rho_o U_o^2}{r}\right)\left(D^2\right) \propto \frac{U_o^3}{r} \tag{1.15}$$

$$III : \frac{1}{4\pi}\frac{\partial}{\partial t}\int_S \left[\frac{\rho v_i}{r}\right] n_i dS \propto \left(\frac{U_o}{D}\right)\left(\frac{\rho_o U_o}{r}\right)\left(D^2\right) \propto \frac{U_o^2}{r}. \tag{1.16}$$

$$II : W \propto p'^2 \propto \frac{U_o^6}{r^2}, \tag{1.17}$$

$$III : W \propto p'^2 \propto \frac{U_o^4}{r^2}. \tag{1.18}$$

1.3 Landing Gear

1.3.1 Geometry

1.3.2 Noise Sources

1.4 Literature Review

1.4.1 Single Cylinder Plasma Flow Control

1.4.2 Tandem Cylinders Plasma Flow Control

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CHAPTER 3

OBJECTIVES AND FUTURE WORK

3.1 Research Objectives

3.2 Proposed Future Work

3.3 Conclusion

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