WKRPT 400
Numerical Analysis and Optimization

A report prepared for:
Altaeros Energies
Somerville, MA

March 24, 2017
Waterloo, Ontario, Canada

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March 24, 2017

Professor Michael Collins
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Dear Professor Collins,

Prepared for my 3B work term at , my third and final work term report is entitled **Numerical Analysis and Optimization**. To perform an in depth numerical structural analysis of the aerostat's key components, the winches.

Altaeros Energies does

As a system engineering intern I did

This report was written entirely by me and has not received any previous academic credit at this or any other institution. I would like to thank. Also, *other words*. No other sources of aid were used for this report.

Best Regards,

Sebastien Blanchet
ID:
3B Mechanical Engineering

Abstract

The objective of this report is

Prelim

Results

Conclusions and recommendations

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Nomenclature

Characters

Symbol	Description	Unit
R	the gas constant	$\mathrm{m}^2 \cdot \mathrm{s}^{-2} \cdot \mathrm{K}^{-1}$
C_v	specific heat capacity at constant volume	$\mathrm{m}^2 \cdot \mathrm{s}^{-2} \cdot \mathrm{K}^{-1}$
C_p	specific heat capacity at constant pressure	$\mathrm{m}^2 \cdot \mathrm{s}^{-2} \cdot \mathrm{K}^{-1}$
E	specific total energy	$\mathrm{m}^2 \cdot \mathrm{s}^{-2}$
e	specific internal energy	$\mathrm{m}^2 \cdot \mathrm{s}^{-2}$
h_T	specific total enthalpy	$\mathrm{m}^2 \cdot \mathrm{s}^{-2}$
h	specific enthalpy	$\mathrm{m}^2 \cdot \mathrm{s}^{-2}$
k	thermal conductivity	$\mathrm{kg} \cdot \mathrm{m} \cdot \mathrm{s}^{-3} \cdot \mathrm{K}^{-1}$
T	temperature	K
t	time	s
p	thermodynamic pressure	$\mathrm{kg} \cdot \mathrm{m}^{-1} \cdot \mathrm{s}^{-2}$
$\hat{p}$	hydrostatic pressure	$\mathrm{kg} \cdot \mathrm{m}^{-1} \cdot \mathrm{s}^{-2}$
$\boldsymbol{f}_b$	body force	$\mathrm{kg} \cdot \mathrm{m}^{-2} \cdot \mathrm{s}^{-2}$
S	boundary surface	m^2
V	volume	m^3
$\boldsymbol{V}$	velocity vector	$\mathrm{m} \cdot \mathrm{s}^{-1}$
u	x component of velocity	$\mathrm{m} \cdot \mathrm{s}^{-1}$
v	y component of velocity	$\mathrm{m} \cdot \mathrm{s}^{-1}$
w	z component of velocity	$\mathrm{m} \cdot \mathrm{s}^{-1}$
c	speed of sound	$\mathrm{m} \cdot \mathrm{s}^{-1}$
$\boldsymbol{r}$	position vector	m
$\mathbf{n}$	unit normal vector	1
$\hat{\mathbf{t}}$	unit tangent vector	1

$\tilde{\mathbf{t}}$	unit bitangent vector	1
C_R	coefficient of restitution	1
Re	Reynolds number	1
Pr	Prandtl number	1
Ma	Mach number	1
α	thermal diffusivity	$\mathrm{m^2 \cdot s^{-1}}$
μ	dynamic viscosity	$\mathrm{kg \cdot m^{-1} \cdot s^{-1}}$
ν	kinematic viscosity	$\mathrm{m^2 \cdot s^{-1}}$
γ	heat capacity ratio	1
ρ	density	$\mathrm{kg \cdot m^{-3}}$
σ_{ij}	stress tensor	$\mathrm{kg \cdot m^{-1} \cdot s^{-2}}$
S_{ij}	deviatoric stress tensor	$\mathrm{kg \cdot m^{-1} \cdot s^{-2}}$
τ_{ij}	viscous stress tensor	$\mathrm{kg \cdot m^{-1} \cdot s^{-2}}$
δ_{ij}	Kronecker tensor	1
I_{ij}	identity tensor	1

Operators

Symbol	Description
Δ	difference
∇	gradient operator
$\delta^{\pm}$	upwind-biased interpolation scheme

Abbreviations

Acronym	Description
ANFO	Ammonium Nitrate Fuel Oil
CFD	Computational Fluid Dynamics
CFL	Courant-Friedrichs-Lewy
CJ	Chapman-Jouguet
EOS	Equation of State
JWL	Jones-Wilkins-Lee
TVD	Total Variation Diminishing
WENO	Weighted Essentially Non-oscillatory
ZND	Zel'dovich-von Neumann-Doering

Section 1

Introduction

This is the introduction, why we are doing this analysis

1.1 Background

Altaeros Energies does this as per Figure 1.1 seen below.

Figure 1.1: Overview of the buoyant airborne technology

1.2 Purpose

The purpose of this report is to do this.

- Do analysis on drum
- Development numerical algorithm for solving

1.3   Scope

The scope of the report will be as follows.

Section 2

Preliminary Analysis

The analysis process is discussed

2.1 Simplifications

The results were simplified to do.

2.1.1 Equations

The first equation that is presented , Equation 2.1

$$\Sigma F_i = 0, \Sigma M_0 = 0 \tag{2.1}$$

2.1.2 Table

This was used to get the results in the following Table 2.1.

Table 2.1: Test table 1

Case	Method #1	Method #2
1	10	50
2	20	100

Section 3

Supplemental

3.0.1   Installation

LaTeX is based on open-source code, so it is available on most computing platforms as free software. If encounter some compiling problems after installation, please Google it. For example, MikTeX may complain about "mathtools.sty", a solution given on "StackExchange" is "The problem is that the package manager has somehow "desynchronized" (even though it's a fresh install). To fix it, run Miktex Package Manager as administrator—"Package Manager (Admin)". Go to Repository–Synchronize. When that completes, your TexWorks should automatically find the needed style files again."

- Linux: TeXLive distribution.

- MacOS: Mactex or TeXLive.

- Windows: MikTeX or TeXLive.

Note: to use LaTeX, you need a text editor for writing and editing ".tex" files. To open the ".tex" files in this template, you need a text editor which supports "UTF-8" encoding. Free options for different platforms are the following:

- Linux: vim.

- MacOS: TeXShop, Macvim.

- Windows: Texmaker, Gvim, Notepad++.

3.0.2   Give a try

After downloading this template and installing a LaTeX distribution. It's time to have a try:

- Linux: run Compile.sh

- MacOS: run Compile.sh

- Windows: run Compile.bat

3.0.3 Include math

LaTeX realization of Equation 3.1 is something like this:

```
\begin{equationa}\label{eq:N-S_equation}
    \frac{\partial (\rho\mathbf{v})}{\partial t} +
    \nabla \cdot (\rho \mathbf{v} \mathbf{v}) =
    -\nabla p + \nabla \cdot\mathbf{T} + \mathbf{f}.
\end{equation}
```

$$\frac{\partial(\rho\mathbf{v})}{\partial t} + \nabla \cdot (\rho\mathbf{v}\mathbf{v}) = -\nabla p + \nabla \cdot \mathbf{T} + \mathbf{f}. \tag{3.1}$$

3.0.4 Include Graphics

Note: inluding figures may seem to be scary by looking at the codes. However, the fact is that you only need to modify the names in each part, the rest are simply copy and paste. These codes are all available in the file "Useful Commands.txt".

Figure 3.1 is an example for including a single figure.

```
\begin{figure}[!htbp]
    \centering
    \includegraphics[width=0.45\textwidth]{ITC_Q_Criteria}
    \caption{An Example for including a single figure}
    \label{fig:ITC_Q_Criteria}
\end{figure}
```

Figure 3.2 is an example for including multiple figuress.

```
\begin{figure}[!htbp]
    \centering
    \begin{subfigure}[b]{0.45\textwidth}
        \includegraphics[width=\textwidth]{HC_OASPL_A}
        \caption{}
        \label{fig:HC_OASPL_A}
```
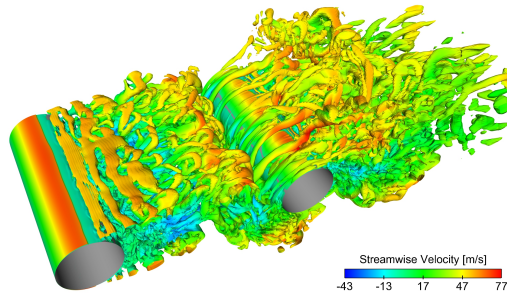
5

Figure 3.1: An Example for including a single graph

```
    \end{subfigure}%
    ~% add a small space
    \begin{subfigure}[b]{0.45\textwidth}
        \includegraphics[width=\textwidth]{HC_OASPL_B}
        \caption{}
        \label{fig:HC_OASPL_B}
    \end{subfigure}%
    \\% change line
    \begin{subfigure}[b]{0.45\textwidth}
        \includegraphics[width=\textwidth]{HC_OASPL_C}
        \caption{}
        \label{fig:HC_OASPL_C}
    \end{subfigure}%
    ~% add a small space
    \begin{subfigure}[b]{0.45\textwidth}
        \includegraphics[width=\textwidth]{HC_OASPL_D}
        \caption{}
        \label{fig:HC_OASPL_D}
    \end{subfigure}%
    \caption{An Example for including multiple figures}
    \label{fig:HC_OASPL}
\end{figure}
```
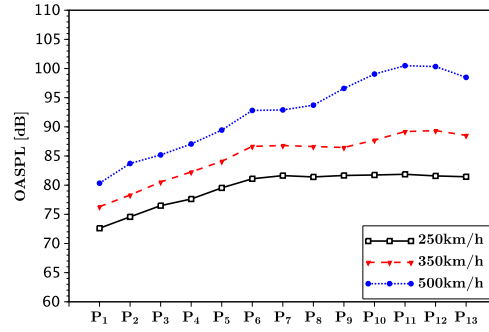
3.0.5   Include a citation

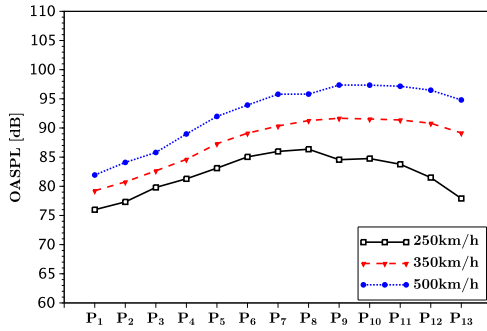Suppose you are going to cite an article named "Document Preparation System", the procedures are:

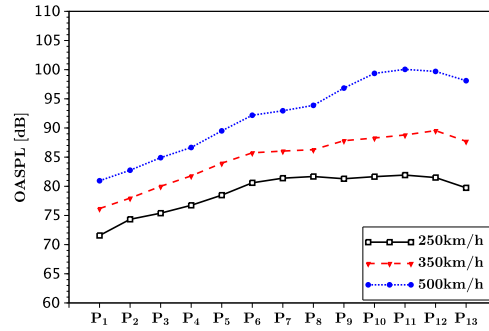- Use Google Scholar search "Document Preparation System".
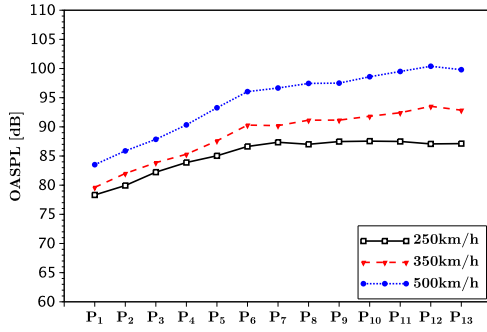
Figure 3.2: An Example for including multiple figures

- Open "Cite" and choose "Import to Bibtex" under the target item.

- Copy the citation information of this article into the file "Myrefs.bib"

- Research dominant: cite this article by `\citep{lamport1986document}` like here [**?**]

- Citation dominant: cite this article by `\citet{lamport1986document}` like here **?**]

- References list is generated automatically.

3.0.6   Generate nomenclature

In this template, a simple command for adding nomenclatures is provided. Therefore, packages for automatical nomenclature generation are not included. From my point of view, there is no need to use those packages and make things complicated. However, if you insist, there are a lot of available packages for creating nomenclatures. Recommended options are (Please Google the one you want to know):

- listofsymbols

- nomencl