![Técnico Lisboa logo]

Thesis Title

Candidate Full Name

Thesis to obtain the Master of Science Degree in

Aerospace Engineering

Supervisor(s):   Prof. Full Name 1
Dr. Full Name 2

Examination Committee

Chairperson: Prof. Full Name
Supervisor: Prof. Full Name 1 (or 2)
Member of the Committee: Prof. Full Name 3

Month Year

Dedicated to someone special...

Declaration

I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

Acknowledgments

A few words about the university, financial support, research advisor, dissertation readers, faculty or other professors, lab mates, other friends and family...

Resumo

Inserir o resumo em Português aqui com o máximo de 250 palavras e acompanhado de 4 a 6 palavras-chave...

Palavras-chave: palavra-chave1, palavra-chave2,...

x

Abstract

Insert your abstract here with a maximum of 250 words, followed by 4 to 6 keywords...

Keywords: keyword1, keyword2,...

Contents

List of Tables

List of Figures

Nomenclature

Greek symbols

α Angle of attack

β Angle of side-slip

κ Thermal conductivity coefficient

μ Molecular viscosity coefficient

ρ Density

Roman symbols

C_D Coefficient of drag

C_L Coefficient of lift

C_M Coefficient of moment

p Pressure

$\mathbf{u}$ Velocity vector

u, v, w Velocity Cartesian components

Subscripts

∞ Free-stream condition

i, j, k Computational indexes

n Normal component

x, y, z Cartesian components

ref   Reference condition

Superscripts

*   Adjoint

T   Transpose

Glossary

CFD   Computational Fluid Dynamics

CSM   Computational Structural Mechanics

MDO   Multi-Disciplinar Optimization

Chapter 1

Introduction

Insert your chapter material here...

1.1 Motivation

Relevance of the subject...

1.2 Topic Overview

Provide an overview of the topic to be studied...

1.3 Objectives and Deliverables

Explicitly state the objectives set to be achieved with this thesis...

Also list the expected deliverables.

1.4 Thesis Outline

Briefly explain the contents of the different chapters...

Chapter 2

Background

Insert your chapter material here...

2.1   Theoretical Overview

Some overview of the underlying theory about the topic...

2.2   Theoretical Model 1

The research should be supported with a comprehensive list of references. These should appear whenever necessary, in the limit, from the first to the last chapter.

A reference can be cited in any of the following ways:

- Citation mode #1 -   [1]

- Citation mode #2 -   Marta and Suleman [1]

- Citation mode #3 -   [1]

- Citation mode #4 -   Marta and Suleman [1]

- Citation mode #5 -   [1]

- Citation mode #6 -   Marta and Suleman 1

- Citation mode #7 -   1

- Citation mode #8 -   Marta and Suleman

- Citation mode #9 -   2021

- Citation mode #10 -   [2021]

The references may include books [1], articles in journals [2], part of a collection of books [3], articles in conferences [4], master theses [5] and PhD theses [6].

Several citations can be made simultaneously as [7, 8].

This is often the default bibliography style adopted (numbers following the citation order), according to the options:

\usepackage{natbib} in file Thesis_Preamble.tex,

\bibliographystyle{abbrvnat} in file Thesis.tex.

Notice however that this style can be changed from numerical citation order to authors' last name with the options:

\usepackage[numbers]{natbib} in file Thesis_Preamble.tex,

\bibliographystyle{abbrvunsrtnat} in file Thesis.tex.

Multiple citations are compressed when using the sort&compress option when loading the natbib package as \usepackage[numbers,sort&compress]{natbib} in file Thesis_Preamble.tex, resulting in citations like [9–20].

2.3 Theoretical Model 2

Other models...

Chapter 3

Implementation

Insert your chapter material here...

3.1 Numerical Model

Description of the numerical implementation of the models explained in Chapter 2...

If needed, pseudo-codes can be included as exemplified in Algorithm 1.

Algorithm 1 Euclid's algorithm

1: **procedure** EUCLID(a, b)   ▷ The g.c.d. of a and b
2:     $r \leftarrow a \bmod b$
3:     **while** $r \neq 0$ **do**   ▷ We have the answer if r is 0
4:         $a \leftarrow b$
5:         $b \leftarrow r$
6:         $r \leftarrow a \bmod b$
7:     **end while**
8:     **return** b ▷ The gcd is b
9: **end procedure**

3.2 Verification and Validation

Basic test cases to compare the implemented model against other numerical tools (verification) and experimental data (validation)...

Chapter 4

Results

Insert your chapter material here...

4.1 Problem Description

Description of the baseline problem...

4.2 Baseline Solution

Analysis of the baseline solution...

4.3 Enhanced Solution

Quest for the optimal solution...

4.3.1 Figures

Insert your section material and possibly a few figures...

Make sure all figures presented are referenced in the text!

The caption should appear below the figure.

Images

Make reference to Figures 4.1 and 4.2.

By default, the supported file types are *.png,.pdf,.jpg,.mps,.jpeg,.PNG,.PDF,.JPG,.JPEG*.

See `http://mactex-wiki.tug.org/wiki/index.php/Graphics_inclusion` for adding support to other extensions.

Figure 4.1: Caption for figure.

(a) Airbus A320

(b) Bombardier CRJ200

Figure 4.2: Some aircrafts.

Drawings

Insert your subsection material and for instance a few drawings...

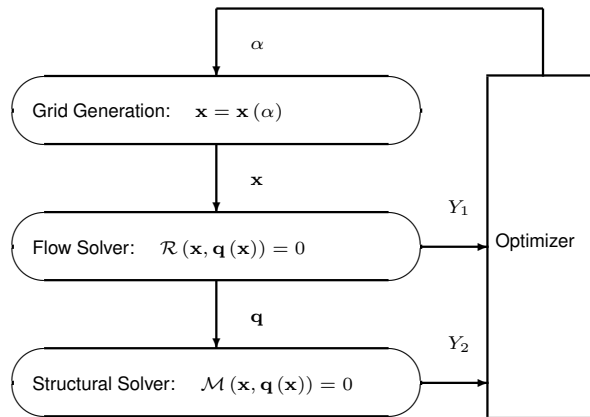The schematic illustrated in Fig.4.3 can represent some sort of algorithm.

Figure 4.3: Schematic of some algorithm.

4.3.2 Equations

Equations can be inserted in different ways.

The simplest way is in a separate line like this

$$\frac{\mathrm{d}q_{ijk}}{\mathrm{d}t} + \mathcal{R}_{ijk}(\mathbf{q}) = 0\,. \tag{4.1}$$

If the equation is to be embedded in the text. One can do it like this $\partial\mathcal{R}/\partial\mathbf{q} = 0$.

It may also be split in different lines like this

$$
\begin{aligned}
\text{Minimize} \quad & Y(\alpha, \mathbf{q}(\alpha)) \\
\text{w.r.t.} \quad & \alpha\,, \\
\text{subject to} \quad & \mathcal{R}(\alpha, \mathbf{q}(\alpha)) = 0 \\
& C(\alpha, \mathbf{q}(\alpha)) = 0\,.
\end{aligned}
\tag{4.2}
$$

It is also possible to use subequations. Equations (4.3a), (4.3b) and (4.3c) form the Naver–Stokes equations (4.3).

$$\frac{\partial\rho}{\partial t} + \frac{\partial}{\partial x_j}\left(\rho u_j\right) = 0\,, \tag{4.3a}$$

$$\frac{\partial}{\partial t}\left(\rho u_i\right) + \frac{\partial}{\partial x_j}\left(\rho u_i u_j + p\delta_{ij} - \tau_{ji}\right) = 0\,, \quad i = 1, 2, 3\,, \tag{4.3b}$$

$$\frac{\partial}{\partial t}\left(\rho E\right) + \frac{\partial}{\partial x_j}\left(\rho E u_j + p u_j - u_i\tau_{ij} + q_j\right) = 0\,. \tag{4.3c}$$

4.3.3 Tables

Insert your subsection material and for instance a few tables...

Make sure all tables presented are referenced in the text!

The caption should appear above the table.

Follow some guidelines when making tables:

- Avoid vertical lines

- Avoid "boxing up" cells, usually 3 horizontal lines are enough: above, below, and after heading

- Avoid double horizontal lines

- Add enough space between rows

Table 4.1: Table caption.

Model	C_L	C_D	C_{My}
Euler	0.083	0.021	-0.110
Navier–Stokes	0.078	0.023	-0.101

Make reference to Tab.4.1.

Tables 4.2 and 4.3 are examples of tables with merging columns:

Table 4.2: Memory usage comparison (in MB).

	Virtual memory [MB]	
	Euler	Navier–Stokes
Wing only	1,000	2,000
Aircraft	5,000	10,000
(ratio)	$5.0\times$	$5.0\times$

Table 4.3: Another table caption.

	$w = 2$			$w = 4$		
	$t = 0$	$t = 1$	$t = 2$	$t = 0$	$t = 1$	$t = 2$
$dir = 1$						
c	0.07	0.16	0.29	0.36	0.71	3.18
c	-0.86	50.04	5.93	-9.07	29.09	46.21
c	14.27	-50.96	-14.27	12.22	-63.54	-381.09
$dir = 0$						
c	0.03	1.24	0.21	0.35	-0.27	2.14
c	-17.90	-37.11	8.85	-30.73	-9.59	-3.00
c	105.55	23.11	-94.73	100.24	41.27	-25.73

An example with merging rows can be seen in Tab.4.4.

Table 4.4: Yet another table caption.

ABC	header			
	1.1	2.2	3.3	4.4
IJK	group		0.5	0.6
			0.7	1.2

If the table has too many columns, it can be scaled to fit the text widht, as in Tab.4.5.

Table 4.5: Very wide table.

Variable	a	b	c	d	e	f	g	h	i	j
Test 1	10,000	20,000	30,000	40,000	50,000	60,000	70,000	80,000	90,000	100,000
Test 2	20,000	40,000	60,000	80,000	100,000	120,000	140,000	160,000	180,000	200,000

4.3.4 Mixing

If necessary, a figure and a table can be put side-by-side as in Fig.4.4

Legend		
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Figure 4.4: Figure and table side-by-side.

Chapter 5

Conclusions

Insert your chapter material here...

5.1 Achievements

The major achievements of the present work...

5.2 Future Work

A few ideas for future work...

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Appendix A

Vector calculus

In case an appendix if deemed necessary, the document cannot exceed a total of 100 pages...

Some definitions and vector identities are listed in the section below.

A.1   Vector identities

$$\nabla \times (\nabla \phi) = 0 \tag{A.1}$$

$$\nabla \cdot (\nabla \times \mathbf{u}) = 0 \tag{A.2}$$

Appendix B

Technical Datasheets

It is possible to add PDF files to the document, such as technical sheets of some equipment used in the work.

B.1 Some Datasheet

SUNPOWER™

C60 SOLAR CELL
MONO CRYSTALLINE SILICON

SUNPOWER™

C60 SOLAR CELL
MONO CRYSTALLINE SILICON

BENEFITS

Maximum Light Capture
SunPower's all-back contact cell design moves gridlines to the back of the cell, leaving the entire front surface exposed to sunlight, enabling up to 10% more sunlight capture than conventional cells.

Superior Temperature Performance
Due to lower temperature coefficients and lower normal cell operating temperatures, our cells generate more energy at higher temperatures compared to standard c-Si solar cells.

No Light-Induced Degradation
SunPower n-type solar cells don't lose 3% of their initial power once exposed to sunlight as they are not subject to light-induced degradation like conventional p-type c-Si cells.
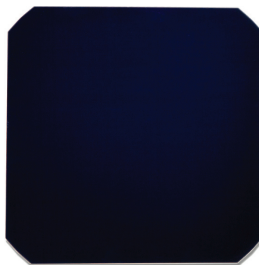
Broad Spectral Response
SunPower cells capture more light from the blue and infrared parts of the spectrum, enabling higher performance in overcast and low-light conditions.

Broad Range Of Application
SunPower cells provide reliable performance in a broad range of applications for years to come.

The SunPower™ C60 solar cell with proprietary Maxeon™ cell technology delivers today's highest efficiency and performance. The anti-reflective coating and the reduced voltage-temperature coefficients provide outstanding energy delivery per peak power watt. Our innovative all-back contact design moves gridlines to the back of the cell, which not only generates more power, but also presents a more attractive cell design compared to conventional cells.

SunPower's High Efficiency Advantage

22,4 % In Production Today

— Average production efficiency

Solar Cell Efficiency (%): Thin Film, Conventional, SunPower Gen B, SunPower Gen C
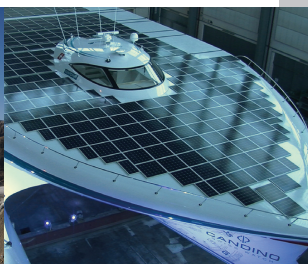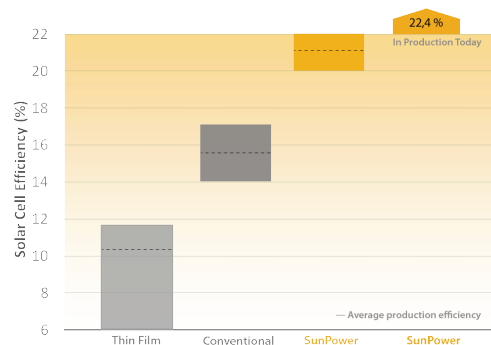
Photo courtesy of 3S Photovoltaics

Electrical Characteristics of Typical Cell at Standard Test Conditions (STC)

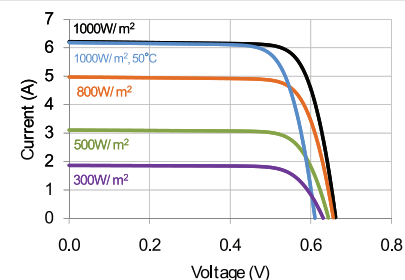STC: 1000W/m², AM 1.5g and cell temp 25°C

Bin	Pmpp (Wp)	Eff. (%)	Vmpp (V)	Impp (A)	Voc (V)	Isc (A)
G	3.34	21.8	0.574	5.83	0.682	6.24
H	3.38	22.1	0.577	5.87	0.684	6.26
I	3.40	22.3	0.581	5.90	0.686	6.27
J	3.42	22.5	0.582	5.93	0.687	6.28

All Electrical Characteristics parameters are nominal
Unlaminated Cell Temperature Coefficients
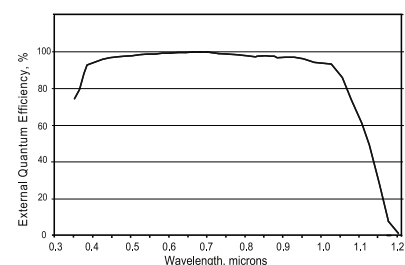Voltage: -1.8 mV / °C   Power: -0.32% / °C

Positive Electrical Ground

Modules and systems produced using these cells must be configured as "positive ground systems".

TYPICAL I-V CURVE

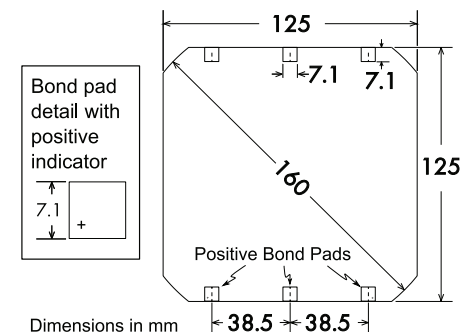1000W/m²
1000W/m², 50°C
800W/m²
500W/m²
300W/m²

Current (A) vs Voltage (V)

SPECTRAL RESPONSE

External Quantum Efficiency, % vs Wavelength, microns

Physical Characteristics

Construction:	All back contact
Dimensions:	125mm x 125mm (nominal)
Thickness:	165μm ± 40μm
Diameter:	160mm (nominal)

Cell and Bond Pad Dimensions

Bond pad detail with positive indicator

125
7.1   7.1
7.1
160
125
+
Positive Bond Pads
38.5   38.5
Dimensions in mm

Bond pad area dimensions are 7.1mm x 7.1mm
Positive pole bond pad side has "+" indicator on leftmost and rightmost bond pads.

Interconnect Tab and Process Recommendations
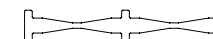
Tin plated copper interconnect. Compatible with lead free process.

Packaging

Cells are packed in boxes of 1,200 each; grouped in shrink-wrapped stacks of 150 with interleaving. Twelve boxes are packed in a water-resistant "Master Carton" containing 14,400 cells suitable for air transport.

Interconnect tabs are packaged in boxes of 1,200 each.

About SunPower

SunPower designs, manufactures, and delivers high-performance solar electric technology worldwide. Our high-efficiency solar cells generate up to 50 percent more power than conventional solar cells. Our high-performance solar panels, roof tiles, and trackers deliver significantly more energy than competing systems.