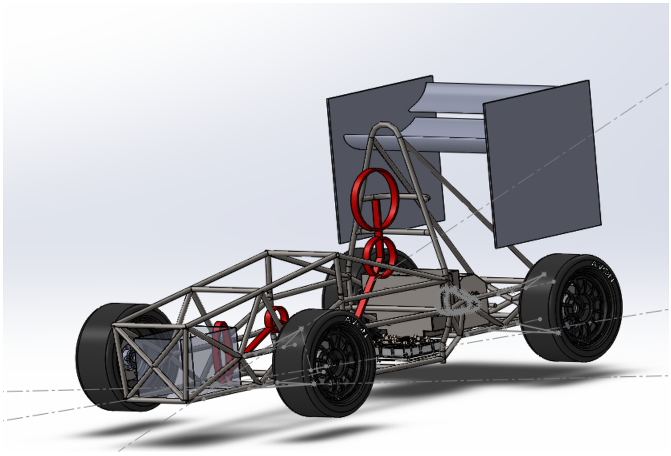
DESIGN OF REAR WING OF AN ELECTRIC RACE CAR



Steffan Johan Kirk – S170816
Carl-Emil Grøn Christensen – S170817
Department of Mechanical Engineering, Technical University of Denmark

Supervisor:
Jens Walther
Department of Mechanical Engineering, Technical University of Denmark

August 2018

Acknowledgements

We would like to thank our supervisors Jens Walther and Robert Mikkelsen, who allowed us to work on a project we hold very dear. The project let us perform incredibly well for a first time racer at the Formula Student competition in Silverstone, and the Vermilion Racing team will hopefully live on many years ahead.

Furthermore, a big thanks to Rasmus from Philips Lighting, for helping us machine the 1/4 scale wing used in the windtunnel tests.

Abstract

Race cars wooo! Formula studee3333nt

Contents

1

Introduction

Vermilion Racing is a newly started Electric race car team building their first vehicle: The Eevee [1]. The teams' purpose is competing against other Universities at the Silverstone race track from the 11^{th} to the 16^{th}. As members of the team, the purpose of this report is to document the design process of the rear wing of the first car, the Eevee, and provide an aerodynamic package documenting drag and downforce. The intent is to start a student organization, passing on the teachings of racecar mechanics for many years to come.

Aerodynamics is a major decider in racing today. Cornering, not top speed is the deciding factor amongst the teams, and aerodynamics is the key. Drag, lift and side force are the three cornerstones to vehicle aerodynamics. A car's ability to handle depends on the grip of the tyres, and downforce directly increases grip by increasing the downwards load on the tyres without adding a weight penalty. Additionally, drag directly decreases the speed of a vehicle by increasing air resistance, but is of less importance as the car's in this class have far more accelerative power than the tyres can handle [2]. Designing the bodyworks of Eevee is therefore a dance of downforce.

1.1 Motivation

- Why are we designing this to begin with

1.2 Design Philosophy

- what are we designing for? low weight, high downforce. drag a bit neglegible due to high power motors.

1.3 Design restrictions

2

Theory

First, let's explain what makes a car fast, and what parameters we can change to improve the speed of our car. The car's acceleration can be described by Newton's second law as:

FiXme Note: stort D eller lille d i ligningen?

$$\sum F_x = m\ddot{x} = F \tag{2.1}$$

Where the sum of forces in the x-direction (the direction of travel) can be expressed as the force already pertained by the vehicle, minus the drag force:

$$F - C_D\left(\frac{1}{2}\rho\dot{x}^2 A\right) = m\ddot{x} \tag{2.2}$$

Assuming we're moving at a steady speed, the acceleration is 0, hence

$$F = C_D\left(\frac{1}{2}\rho\dot{x}^2 A\right) \tag{2.3}$$

As we were interested in the speed of the car, let's solve for the velocity. The force is given by $F = \frac{P}{\dot{x}}$, where P is the power of the car, which gives:

$$\dot{x} = \left(\frac{2P}{C_D\left(\rho A\right)}\right)^{\frac{1}{3}} \tag{2.4}$$

This is assuming we're traveling at terminal velocity – that is, the point where the Driving Force = Friction Force. The terminal velocity of the racer is then easily calculated, as the competition restricts the maximum amount of power:

FiXme Note: Muligvis uddyb her

$$\dot{x}_{\max} = \left(\frac{2 \cdot 80\,\mathrm{kW}}{0.85\left(1.225\,\mathrm{kg\,m^{-3}}\ 1.2\,\mathrm{m^2}\right)}\right)^{\frac{1}{3}} = 50\,\mathrm{m\,s^{-1}} = 181.4\,\mathrm{km\,h^{-1}} \tag{2.5}$$

however, given the ruleset a forecasted maximum of $110\,\mathrm{km\,h^{-1}}$ allows a much larger drag coefficient C_D:

$$C_D = \frac{2P}{\dot{x}^3\,(\rho A)} = \frac{2 \cdot 80\,\mathrm{kW}}{(120\,\mathrm{km\,h^{-1}})^3\left(1.225\,\mathrm{kg\,m^{-3}}\;1.2\,\mathrm{m^2}\right)} = 2.82 \qquad (2.6)$$

Thus, the car's top speed will only be limited by a drag factor > 2.82, which is far above the drag introduced by the aerodynamic devices.

From this derivation, it's clear that the car's abilities at maximum speeds far exceed the requirement of the track. Therefore, the next step is to improve cornering speeds which depend strongly on the tyre's grip on the surface of the road [2].

2.1 Aerodynamics

2.2 Vehicle Performance

2.2.1 Improvements in Top Speed

2.2.2 Cornering performance

2.2.3 Load Distribution

3

Simulation

3.1 Star-CCM+

3.2 Finite Volume method

3.3 Mesh Generation

3.4 The Wing

3.4.1 Multi-Element Wing Optimization

Wing was moved around to optimize lift. Here's the results changing the variables.

3.5 The Aerodynamics Package

3.5.1 Undertray, Diffuser, Front Wing and Driver

3.5.2 Everything Together Now

3.6 Results

4

Construction

In order to verify the computational fluid dynamics used, a 1/4 scale wing was constructed. This miniature wing is constructed for performing windtunnel tests, and comparing results with the simulations. If the two are in accordance, the simulated results of the full scale wing can be used with confidence.

4.1 1/4 Scale Wing

The small scale rear wing is constructed in 6 pieces. The large wing is dissected into three parts. Two regular wings, and a central part with 15 pressure taps.

Material selection is based on the ease of machinability - a CNC-miller was provided to us, along with ample amounts of aluminium. This scale wing is not to be used in the actual race car, so weight is not a concern.

4.2 Requirements

FiXme Note: Hvad kræves af styrke fra konkurrencens side? Hvad ønsker holdet?

FiXme Note: Overvej CES (for flair jo)

4.3 Prototyping

4.4 Material Selection

4.5 Molds

4.6 Assembly

4.7 Finish

5

Experiment

5.1 Equipment

5.2 Experimental Procedure

5.3 Results

6

Discussion

7

Conclusion

bla

Perspective

Bibliography

[1] Bulbapedia. http://bulbapedia.bulbagarden.net/wiki/Team_Rocket, may 2016.

[2] Joseph Katz. *Race Car Aerodynamics*. BentleyPublishers, 2nd edition, 2003.

[3] George P. Sutton and Oscar Biblarz. *Rocket Propulsion Elements*. Wiley, 8th edition, 2010.

[4] John D. Clark. *Ignition!: An informal history of liquid rocket propellants*. Rutgers University Press, 1st edition, 1972.

[5] Seppo A. Korpela. *Principles of Turbomachinery*. Wiley, 1st edition, 2012.

[6] James G. Quintiere. *Principles of Fire Behaviour*. Delmar, 1st edition, 1997.

[7] Julio de Paula Peter Atkins. *Atkin's Physical Chemistry*. Oxford University Press, 10th edition, 2014.

[8] Nancy Hall. Compressible Area Ratio. https://www.grc.nasa.gov/www/k-12/airplane/astar.html, May, 2015.

[9] Nancy Hall. Isentropic Flow. https://www.grc.nasa.gov/www/k-12/airplane/isentrop.html, May, 2015.

[10] SierraPine. *MDF Material safety data sheet*, January 2005.

[11] Thermocouples: Using Thermocouples to Measure Temperature. http://www.omega.com/prodinfo/thermocouples.html, 2016.

[12] Richard Nakka. Propellant Grain. http://www.nakka-rocketry.net/th_grain.html, july 2001.

[13] Richard Nakka. Nozzle Theory. http://www.nakka-rocketry.net/th_nozz.html, April 2014.

[14] Robert A. Braeunig. Nozzle. http://www.braeunig.us/space/propuls.htm, 2012.

[15] E659-78. Standard test method for autoignition temperature of chemicals. *ASTM*, 14(5), 2000.

[16] Anders Hjort-Degenkolv Kristensen Alex Nørgaard, Martin Gosvig Jensen. Undersøgelse af regressionsrater i en hybrid raketmotor, 2015.

[17] HorsePunchKid. De laval nozzle. https://en.wikipedia.org/wiki/Rocket_engine_nozzle#/media/File:De_laval_nozzle.svg.

[18] Philip-J. Pritchard Robert W. Fox, Alan T. McDonald. *Introduction to Fluid Mechanics*. Wiley, 6th edition.

[19] Frank M. White. *Fluid Mechanics*. McGraw-Hill Higher Education, 4th edition.

[20] Steven S. Zumdahl. *Chemistry*. Houghton Mifflin, 7th edition.

[21] Enthalpy. http://fchart.com/ees/eeshelp/eeshelp.htm.

[22] Merle C. Potter. *Mechanics of Fluids*. Cengage Learning, 4th edition.

[23] Industrial Measurements Systems Inc IMS. http://imsysinc.com/Knowledgebase/ultratherm.htm.

[24] The Engineering ToolBox. Wood-combustion heat.