Cranfield Formula Electric Series

MSc Advanced Motorsport Engineering
Group Project
May 2015

Cranfield UNIVERSITY

Laura Aime
Anthony Bonnardel
Jean-Hubert Collès
Gery Fossaert
Stuart Kirk
Parth Pratik
Adam Reardon

Introduction

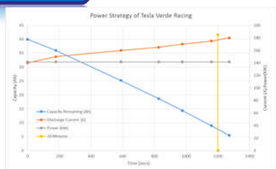
The aim of this project was to undertake a study for the adaptation of the combustion based powertrain used in the defunct Formula BMW series for conversion to a purely electric system. With the cells of the battery set by the CFES, the design covered the dimensioning of the battery and electric components, motor and drivetrain choices, packaging decisions coupled with a detailed thermal analysis due to the heavy reliance temperature has on a batteries performance

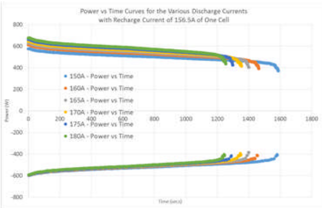
Objectives

- ❖ Define the battery size (number of cells) along with its crash structure
- ❖ Select an appropriate powertrain from existing technology (electric motor, gearbox)
- ❖ Design the thermal management system to ensure maximum performance and safe operation
- ❖ Control the cost

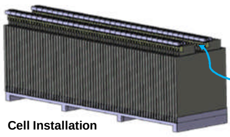
Battery

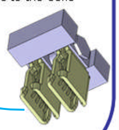
- Two sets of 131 cells in parallel, providing a constant power after thermal losses of 141.62kW
- Power to weight ratio of the cells of 0.621kW/kg
- Total discharge current varies between 280A and 360A
- Total energy discharged after 20 minutes of run time is 136.124MJ (37.81kW.h)
- 19.2% safety margin to complete discharge





- Recharge occurs for 19.9% of the lap
- Packaged to ensure no damage occurs to the cells under normal car operation

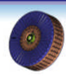

Cell Installation


Busbar Config.

Powertrain & Simulations

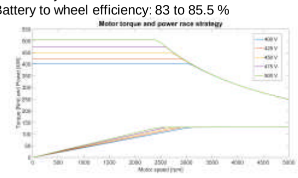
EMRAX 268 motor

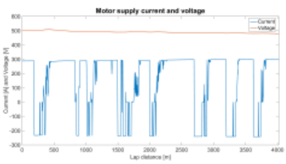
- Field orientation and field weakening control
  - Torque is proportional to current
  - Speed is proportional to voltage
- Electric modelling provided the linkage between motor and battery current
- Battery to wheel efficiency: 83 to 85.5 %

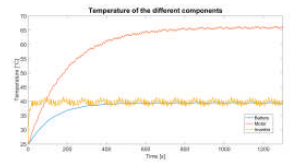


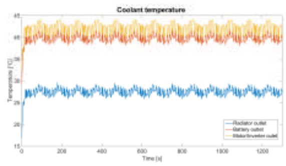
Hewland TMT 200 gearbox

- Gearbox advantages:
  - Improves acceleration
  - Provides constant power
  - Improves energy recovery







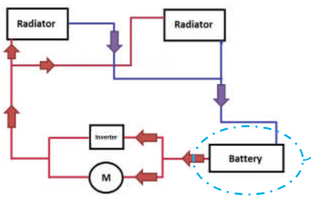


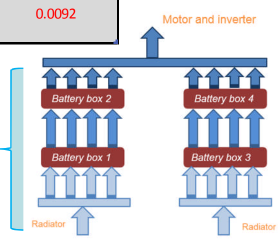
Thermal management

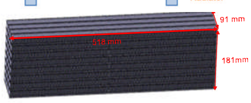
- Cells fully immersed in coolant inside four separated battery boxes
- Type of coolant: Aliphatic (PAO) with 1 % of nanoparticles γ-Alumina Al_2O_3 → Enhanced thermal conductivity and heat transfer coefficient

Properties	ρ (Kg/m3)	Cp(J/Kg.K)	k(W/m.K)	Viscosity (Kg/m.s)
Aliphatic PAO with 1% γ-alumina	762.3	2149.9	0.84	0.0092

Cooling layout:

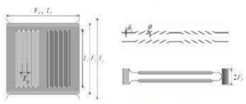






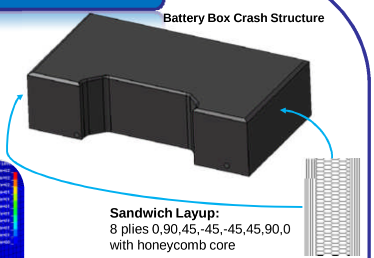
Performances:

- Maximum cell temperature: 43°c
- Coolant outlet temperature: 39.3°c
- Radiator exchange area: 6 m² at each side pod
- Pressure drop: 0.87 bar
- Pumping power: 132.9 W
- Coolant weight: 97 Kg



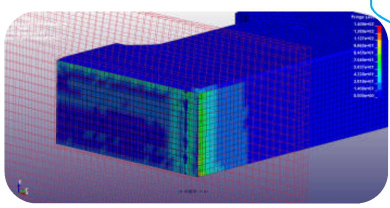
LOUVERED FIN radiators

Structures



Battery Box Structure test criteria

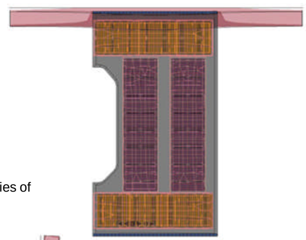
- Battery box impact tested at 35kph on vehicle y-axis (lateral axis)
- Mass of all parts included (cells & coolant fluid)
- No contact of cells or spilling of fluid from structure



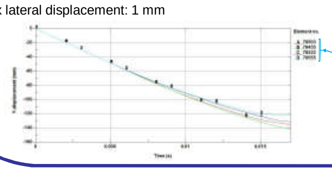
View of Von Misses Stress Result

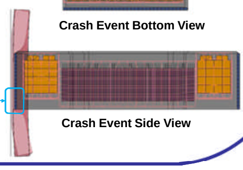
FEA Analysis (LS-Dyna)

- FEA simulations developed using Material Cards 54 "Enhanced Composite Damage" & 26 "Honeycomb" to represent CFRP Sandwich crash structure
- Crash structure consist Al honeycomb sandwiched between 4 plies of T800H/Epoxy
- Max Stress 140.92 MPa
- Max lateral displacement: 1 mm



Crash Event Bottom View





Crash Event Side View

Conclusions

- ✓ Battery sizing produces 136.124 MJ during 20mn race with 19.2% safety margin
- ✓ EMRAX motor with gearbox provide a constant power of 127 KW
- ✓ The thermal management system ensures safe operations of the components at steady state by using direct contact coolant enhanced by nanoparticles. The design has been validated by CFD and Simulink simulations
- ✓ The carbon fibre composite battery box passed the crash test simulation
- ✓ The total weight of the car (without the driver) is 793 Kg and the predicted lap time around Donington Park GP is 1min32.7sec
- ✓ The cost of adapting the Formula BMW to our electric car design would be $81,666

Racing CFES Cranfield Formula Electric Series WILLIAMS ADVANCED ENGINEERING Virgin RACING FORMULA E TEAM

www.cranfield.ac.uk

Cranfield University, SATM, College Road, Cranfield, MK43 0AL

l.aime@cranfield.ac.uk
a.bonnardel@cranfield.ac.uk
j.m.colles@cranfield.ac.uk
g.b.fossaert@cranfield.ac.uk
s.kirk@cranfield.ac.uk
p.pratik@cranfield.ac.uk
a.p.reardon@cranfield.ac.uk