Thermal Model of a Li-ion Battery

Determining the heat transfer of a battery on its surroundings

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Abstract

The Runge-Kutta-Fehlberg (RKF) algorithm was used in a FORTRAN program to evaluate a system of differential equations that describe the movement of charge through a Lithium-ion Battery in a phone. The RKF algorithm uses 4th and 5th order estimates to solve a system of ordinary differential equations that describe complex problems. The program determined the capacity needed to power the device for a total of 14 hours. In order to account for and understand the uncertainty surrounding this solution a sensitivity analysis was performed on the initial charge distribution, voltage demanded from the phone components, and internal resistance of the battery. This analysis provided insight into how change in these parameters would affect the minimum capacity of the phone. The program produced results indicating that the phone battery needed to have 2713.42 (mAh) of charge in order to power the phone for the full period. The sensitivity analysis showed that reducing the voltage demand would be the most efficient use of research and development resources to increase run-time of phones.

Introduction

Lithium-ion batteries are an indispensable technology that have come to power a significant amount of the productivity in the 21st century. One critical parameter important to the performance of lithium-ion batteries is the temperature gradient under a load ("Discharging at High and Low Temperatures" 2019). The thermal conditions of the environment and the temperature gradient of the battery cell have a large influence on the overall performance and energy storage of a Lithium-ion battery. Hence, it will be useful to understand the thermal affects of a battery on its environment while it is under a constant discharge. A battery that runs too cold will risk a drastic increase in internal resistance, which can decrease the overall capacity and length of runtime of the battery ("Discharging at High and Low Temperatures" 2019). Alternatively, running too hot can permanently shorten its lifetime, in addition, high temperatures can potentially damage other electronic components that are in proximity.

A python program was created using the FeniCS and other libraries to thermally model a 3D Lithium-ion battery cell under a constant discharge. The model will help to understand which parameters the largest effect on the temperature gradient within the battery cell, as well as how these affect the performance. Gaining insight into this behavior could help one to create more thorough thermal battery management systems to help improve the efficiency of electric vehicles. Lastly, a sensitivity analysis will be performed on the current, internal resistance of the battery, and thermal conductivity to help in understanding how uncertainty in these values could affect the heat transfer the surroundings of the battery cell.

* Introduce topic
* Provide background info
* Layout goals of project
* Brief method
* SA?

~1pg

Literature Review

* Review papers from similar research topics
* Discuss results

~ 1pg

Methodology

* Briefly review FEA, how it works, Fenics module
* Overall strategy and approach
* Present model PDE’s and boundary conditions, discuss/describe
* Show derivation of variational/weak formulation
* Create visual representation/sketch to discuss, also label boundaries and domain eqns
* Review parameters with units present in a table
* Sensitivity analysis? Current vs heat transfer on boundaries?

~ 2 pgs

Results and Discussion

- present main results

- discuss findings

-present figures / images

- sensitivity analysis?

- implications of SA

~ 1pg

Conclusions

* Summarize results
* Discuss implications
* Suggest further research

~ ½ pg

References

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Appendix