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#### Research Paper

## Electrochemical thermal modeling and experimental measurements of 18650 cylindrical lithium-ion battery during discharge cycle for an EV



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#### HIGHLIGHTS

- Designed and developed the battery thermal testing system.
- Developed ECT model using ANSYS Fluent.
- Studied the temperature and voltage profile at different discharge rates.
- Validated the model with the experimental data.

#### ARTICLE INFO

#### Keywords: Lithium-ion battery Electrochemical thermal model Thermal analysis ANSYS

#### ABSTRACT

Study of thermal performance in lithium-ion battery cell is crucial which directly affects the safety. Even though the operation of a lithium-ion battery cell is transient phenomena in most cases, most available thermal models for lithium-ion battery cell predicts only steady-state temperature fields. This paper presents a mathematical model to predict the transient temperature and voltage distributions of 18650 cylindrical lithium-ion battery at different discharge rates. For this, the 18650 cylindrical lithium-ion battery cell is tested inside the lab with an air-cooling method by four thermocouples mounted on the battery surface under four constant current discharge rates of 1 C, 2 C, 3 C, and 4 C in order to provide quantitative data regarding thermal behavior of lithium-ion batteries. Later, the numerical model is developed using ANSYS CFD software and it is found that the model predictions are in good agreement with experimental data for temperature and voltage profiles. The highest temperature is 46.86 °C at 4 C discharge rate as obtained from simulation. The results also show that the increased C-rates results in increased temperature on the principle surface of the battery.

#### 1. Introduction

Increasing environmental awareness and depleting fuels sources are the main issues in the automotive industry and therefore, electric vehicles (EVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCVs) are projected as one of the most sustainable solutions for future transport. These days, lithiumion batteries are gaining widespread acceptance in the development of EVs, HEVs, and PHEVs due to: (1) high specific energy and power densities [1]; (2) high nominal voltage and low self-discharge rate [2]; and (3) long cycle-life and no memory effect [3]. To extend the life of battery, precautions must be taken during discharging and charging since, for example exceeding voltage, current or power limits may result in battery cell damage. The possibility of thermal runaways also occurs if care is not properly taken [4]. Moreover, lithium-ion polymer

batteries must be carefully monitored and managed (electrically and thermally) to avoid safety (inflammability) and performance related issues [5–8].

There are various papers in the open literature available for battery thermal modeling, using different approaches such as artificial neural network [9–11], finite element model (FEM) [12] or lumped parameter model (LPM) [13], linear parameter varying (LPV) model [14], or partial differential equation (PDE) model [15], CFD models [16–18]. Battery modeling based on electrochemical equations provides a deep understanding of the physical and chemical process inside the battery which makes it useful when designing a cell, but high computational time makes these models improper for applications with high dynamics. The first electrochemical modeling approach to porous electrodes with battery applications was presented by Newman and Tiedemann in 1975 [19]. In the porous electrode theory, the electrode is treated as a

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solid/electrolyte interfacial area per unit volume or active surface area per electrode unit volume for electron transfer reactions 11/cml  A area Ins <sup>-1</sup> System feet to appacity [J/kg °C]  Specific heat for positive tab [J/kg kK]  Specific heat for positive tab [J/kg kK]  Concentration of lithium in solid phase [mol/m²]  Concentration of lit	Nomenclature ∇ gradient operator				
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