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Some investigations on experimental and simulation results of EV Battery pack to provide ideal operating temperature for battery safety

Atharva Koli[1], Abhishek Patil[2], Durwas Khot[3], Kaushal Kedar[4], Nikhil V. Khatekar[5]

[1,2,3,4] *Department of Mechanical Engineering, PCT's A P Shah Institute of Technology, Thane Affiliated to University of Mumbai, India.*

[5]*Professor, Department of Mechanical Engineering, PCT's A P Shah Institute of Technology, Thane Affiliated to University of Mumbai, India.*

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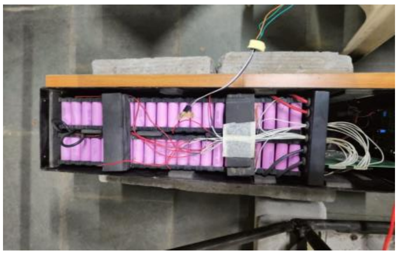
Abstract: The battery also referred to as a chemical energy storage device—generates the required electrical energy. A cell is the basic component of a battery that produces energy. The significance of personal safety of person and vehicle service security has brought attention to battery thermal safety issues in recent years. To meet the anticipated problems and assure battery safety, the most recent innovations in battery thermal management (BTM) are being done. With a heat transfer intensify technique, the BTM technology improves battery safety while ensuring battery operation performance based on the battery's thermo-kinetic, mechanical, and electrochemical characteristics under both normal as well as abnormal operating settings. It is also crucial to prevent overheating and provide the optimal operating temperature for safe operation. Hence, creating a BTM system that is both secure and reliable. In this investigation, thermal calculations based on experimental data were performed and the outcomes of the ANSYS simulation were compared. It was found that the cell's highest temperature in ANSYS was 31.6°C, which was close to cell's average temperature. This temperature was in good agreement with the temperature obtained during actual testing (31.6°C).

Key Word: Battery Thermal Management System, Li-ion batteries, Battery components.

1. Introduction

Electric vehicles with different power trains include electric motorcycles and scooters. A rechargeable Li-ion battery provides energy to power electric motors. Electric scooters have a step-through structure. Electric bicycles are comparable to other vehicles, but they differ from them in that they may still move forward when the user pedals in addition to using batteries, in contrast to motorcycles, which are straddled. Uncertainty surrounds the early history of electric motorcycles. Ogden Bolton Jr. of Canton, Ohio, submitted a patent application for an "electrical bicycle" on September 19, 1895. Hosea W. Libbey of Boston submitted a second patent application for an "electric bicycle" on November 8 of the same year.(1)

The Li-ion battery is a type of rechargeable battery that performs reversible reduction of ions to store energy. The frequently used types of batteries in electric vehicles are Lithium polymer and Lithium-ion batteries. Lithium-ion batteries are used in mobility and aerospace applications as well as grid scale energy storage. Also, it is the most common kind of battery used in EVs and other battery storage systems.(3) For choosing the best Battery Thermal Management System (BTMS), understanding the impact of heat is very important. The internal operating cell temperature determines the characteristics like - performance, safety and lifetime of Lithium-ion batteries, making thermal analysis of battery cells essential and important. Compared to other rechargeable battery technologies, lithium-ion batteries offer high energy densities and less self-discharge. Lithium-ion batteries have the possibility of catching fire or exploding if not properly charged or if it is broken, as cells of Lithium-ion batteries have volatile electrolytes and can provide a safety risk if improperly manufactured. Many advancements have been made in Lithium-ion batteries. Heat is usually produced inside the lithium ion battery while charging which shortens battery's lifetime and lower its performance over the period of time. Batteries can catch fire and produce dangerous wastes if not properly handled while recycling, especially when they include poisonous metals, as a result EV's driving range and acceleration outputs are decreased. Also, while discharging, heat is produced in cells when the vehicle is in motion. In order to maintain peak performance and to



offer better thermal management for lithium-ion batteries, the electric vehicle needs a cooling technique.(5)

Figure 1: Actual Battery Setup

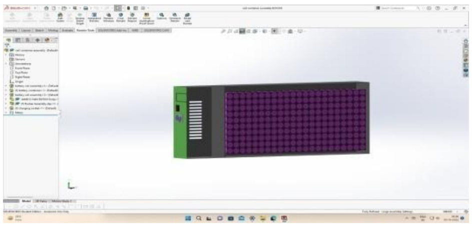


Figure 2: CAD model of Battery

2. Methodology

- Study of Electric Vehicle's battery and system parameters
  Analysis of Li-ion batteries of Electric vehicles and detailed study on battery cells and structure of battery packs.
- Battery heating calculations and simulation based on different parameters
  Mathematical calculations and Ansys simulation of battery cells was done based on the different parameters.
- Testing validation of battery heating using thermocouples in Arduino
  Actual testing of battery heating was done using LM 35 temperature sensor and Arduino mega and Arduino IDE software.

Project details

Motor selection

As per market research most two wheelers are equipped with motor power output of 6 to 10 kW approximately. So, we decided to consider an 8-kW power output motor. Based on this selection we searched for suitable motors available in the market. Motor selected was QS Motor 13X3.5 inch 273 V4 8000W 50H E-Motorcycle In-Wheel Hub Motor. This is a high power electric motor which consumes peak current of 254A and runs on 96 V emf producing 272 Nm of max torque.

Motor

Rated Power	8 kW
Peak Power	23 kW
Rated Voltage	96 V
Speed	1690 RPM
Max Torque	272 Nm
Cont. Battery Current	83 A
Peak Battery Current	254 A

Table 1: Motor

Battery heating calculations

After selecting the battery, we did hand calculations as well as simulation for battery heating to validate those results. For hand calculations we took reference from research papers and calculated single cell temperature under various loads. We considered 92% motor efficiency as mentioned in the motor datasheet and 95% motor controller efficiency.(2)

Component Parameters

Thermal analysis of ICR18650-26JM cell Specifications:
Cell - Nominal Voltage: 3.63 V Nominal Capacity: 2600 mAh
Battery pack – Voltage: 48 V
Capacity: 78 Ah Motor – Power: 1.5 kW

Max. peak current: 41.6 A

Calculations

Power (P) = VI

Therefore, I = 1500/48 = 31.25 A = 32 A Rated current (IR) = 32A @0.41C

Peak current (IP) = 41.6A @0.53 Battery current (IB) = 78A @1C Cell current (Ic) = 1.378 A = 1.35 A

Heat Generated (Q) = 1.35 X 1.35 X 78 X 10-3 = 0.1421 W

Ansys Simulation

Simulation of single cell was performed on the single ICR18650-26JM cell Boundary conditions - Ambient temperature: 31 deg C

Heat generated: 0.1421 W

Result - Temperature of the cell: Max. Temperature: 31.172 deg C

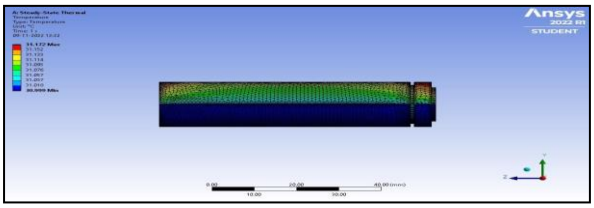


Figure 3: Thermal analysis of single cell

Testing and Validation

Testing was performed on an existing battery pack to measure cell heating in the battery pack. The test set-up was built and the motor was operated to the operating battery parameters. Sensors were connected on the selected individual cells and average temperature was recorded on the Arduino IDE software.(4)

The test set-up was comprised for following components –

1. Electric motor (QS Motor E-Motorcycle In-Wheel Hub Motor)
2. Electric controller (QS Motor controller)
3. Battery pack (Li-ion cells)
4. Multimeter
5. Arduino UNO circuit
6. LM35 Temperature sensors
7. Laptop (Arduino IDE software)
8. Connection wires
9. Bread board

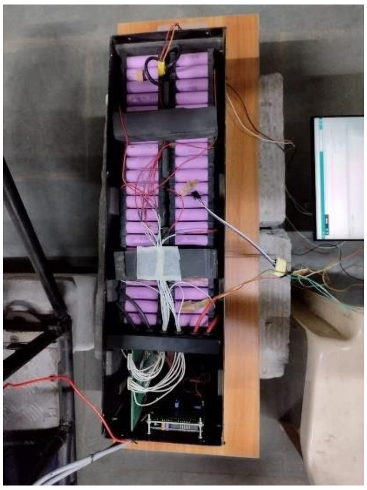


Figure 4: Battery Pack

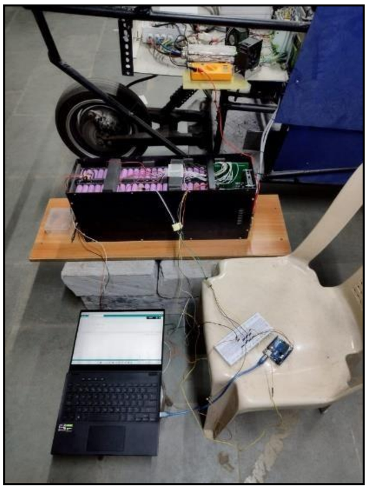


Figure 5: Heating Test Setup

Testing Code

```
int  val;
int  tempPin = 1;
void setup ()  {
serial.begin (9600);
}
void loop() { R
val = analogRead (tempPin);
float  mv = (val / 1024.0) * 5000;
float  cel = mv / 10;
float  farh = (cel * 9) / 5 + 32;
serial.print ("TEMPERATURE = ");
serial.print (cel);
serial.print ("*C");
serial.println ();
delay (1000);
/* uncomment this to get temperature in fahrenheit
serial.print("TEMPERATURE = ");
serial.print (farh);
serial.print ("*F");
 serial.println ();
 */
 }
```

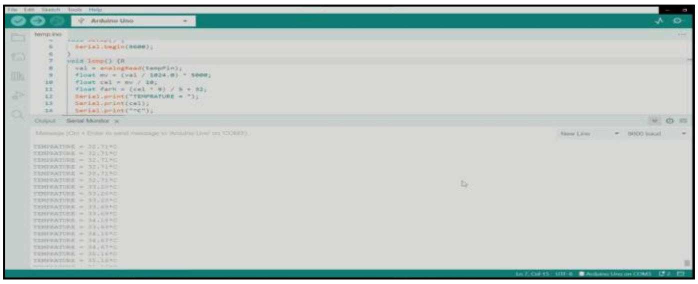


Figure 6: Test results

3. Results

- After successful completion of the test on the battery pack, we compared the simulation and actual test results.
- We validated the calculations and concluded that the calculations are correct. In simulation we got the max.
- The temperature of the cell was 31.6 deg Celsius which was close to the average temperature of the cell as 31.9 deg Celsius which was measured during actual testing.

4. Conclusions

- We calculated the battery cell heating using theoretical calculations and performed Ansys simulation for the temperature value. After successful completion of the testing, it is concluded that the theoretical calculations and Ansys simulations are correct and validated using actual testing on the battery and motor.

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