Proceedings of the 18th UK Heat Transfer Conference
9-11 September 2024, Birmingham
UKHTC2024-041

CONJUGATE HEAT TRANSFER ANALYSIS OF A POUCH CELL LI-ION BATTERY PACK USING MINI CHANNEL COLD PLATES WITH A U-SHAPED CONFIGURATION

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1. ABSTRACT

In this study, a cold plate with U-shaped channels is investigated to cool the adjacent pouch cell Li-ion batteries. The U-shaped cold plate consists of two parallel sets of channels with seventeen mini channels to cover the whole surface area of the batteries. The thermal management system is evaluated based on the maximum and uniformity of the surface temperature of the batteries. The important geometrical features of the U-shaped channels are studied toward a higher performance of the system. The cold plates are designed based on the electrical requirements for placing the bus bar as well as the safety of the battery pack operation. The material of the cold plate is PEEK which can tolerate the expansion of the pouch cell batteries during charging. The results show that for the flow rate of 1 LPM and flow inlet temperature of 25 °C and the heat input of 16 W for the batteries, the average and maximum surface temperature of the batteries are achieved at 28°C and 30°C, respectively, showing the acceptance of the employed U-shaped cold plate. A uniform temperature distribution of the battery's surface is achieved. By increasing the heat generation to 32 W, the average and maximum temperatures raise to 31 °C and 35 °C, respectively.

2. INTRODUCTION

With the growing popularity of electric vehicles (EVs), the need for efficient thermal regulation of lithium-ion batteries (LIBs) becomes increasingly crucial [1]. These components are widely adopted in EVs owing to advantages like high storage density, long service life, and environmental friendliness. However, these batteries are susceptible to temperature-related challenges that can impact their performance, longevity, and safety [2]. During the charge and discharge cycles, LIBs experience internal heat generation that can lead to excessive temperatures and spatial/temporal temperature gradients if not properly regulated. If not properly managed, this heat can lead to a rise in cell temperature, which can have detrimental effects on the battery's overall functionality [3]. Different methods have been used widely for thermal management of various types of Li-ion batteries including cylindrical, pouch and prismatic.

Pouch cell batteries are typically cooled by inserting a cold plate between the cells, where the coolant flowing within the cold plate transfers heat from the batteries to the coolant. However, utilizing cold plates

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for pouch cell batteries presents several challenges. These include the expansion of cells during charging and discharging, accommodating electrical connections, ensuring safety, etc [4].

The purpose of this study is to evaluate the effectiveness of a cold plate made from a semi-crystalline thermoplastic material called PEEK. The cold plate performance is designed for cooling and inserting the tabs using pouch cell batteries. PEEK is often used as the body for electrical connectors to minimize thermal expansion, provide chemical resistance, and to promote effective sealing [5]. The cold plates also enhanced by implementing U-turn configuration to increase the heat transfer area. Different criteria including the surface temperature of the batteries, the uniformity of temperature distribution and the velocity distribution are analysed. The results of this research are anticipated to be integrated into a battery pack with thirteen cells, showcasing the practical application and potential benefits of the innovative thermal management strategies developed through this study and further experimental development of the battery pack.

3. METHDOLOGY

In this study, a cold plate is utilized for temperature management of adjacent pouch cell batteries. Fig. 1 illustrates the schematic of the cold plate, designed to accommodate the batteries placed on their sides. The top of the cold plate features larger dimensions to allow for the placement of tabs, which adhere to the cold plate. This design not only cools the battery but also facilitates the cooling of the tabs. The cold plate is equipped with 17 mini-channels on each side, utilizing a U-turn flow to increase the contact surface area, thereby enhancing the efficiency of the thermal management system.

Due to the expansion of pouch cell batteries during charging and discharging cycles, this project utilizes PEEK, a semi-crystalline thermoplastic material, for the cold plate. Given PEEK's low thermal conductivity, the cold plate's thickness is minimized, leveraging additive manufacturing and 3D printing technologies for efficiency. Water/glycol is used as the coolant due to its superior thermal properties compared to pure water. Ansys-FLUENT software is used to solve the governing equations suing simple algorithm. The thermophysical properties of the coolant and PEEK materials are then adjusted in the software.

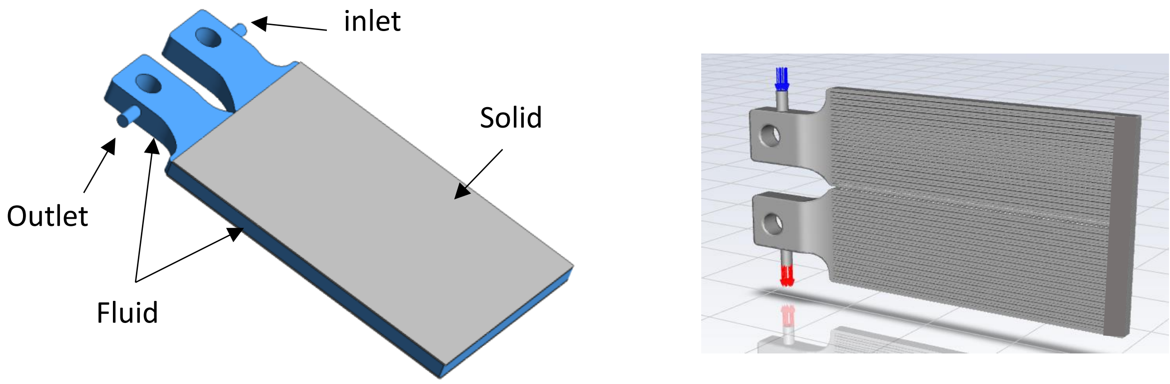

Fig. 1 Cooling cycle in the car including the battery pack and heat pump circuits.

4. RESULTS

Fig. 2 shows the contour plots of the temperature distribution for different charging rates corresponding different heat input of 16 and 32 W on the surface of the batteries for the flow rate of 1 lpm. As shown, the system is capable to manage the temperature of the batteries. Even for the heat input of 32 W which is based on the fast-charging concept. As shown, for the case of 32 W heat input, the average temperature is around 31 °C while the maximum is only 4 °C higher than the average temperature.

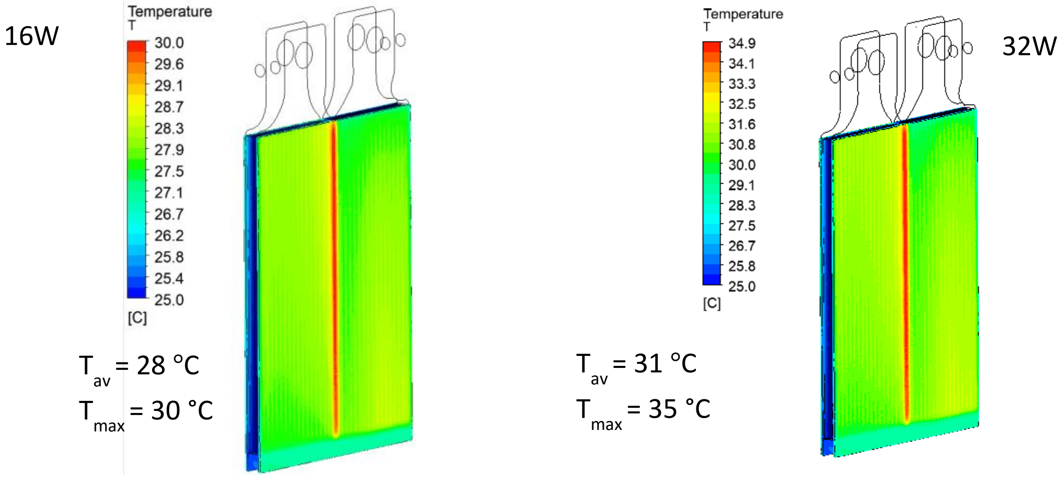

Fig. 2 Temperature contour plots for different heat input

5. CONCLUSIONS

Thermal management of a pouch cell battery pack was evaluated cooled by a cold plate with U-shaped channels. Various concepts including the maximum and uniformity of the surface temperature and the flow inside the mini channels of the cold plate were investigated. The results prove the capability of the cold plate on the uniformity of the battery's surface temperature for different charging rates. The average and maximum surface temperature of the battery is 31 °C and 35 °C, respectively, at high heat generation of 32 W. This study provides a systematic design for using a U-shaped cold plate for the thermal management of pouch cell Li-ion batteries and provides guidelines for an optimized thermal management system. The system designed in this study is going to be manufactured, assembled, and tested experimentally.

Acknowledgements

This work was supported by the Faraday Challenge Round 5 [Project number 10041430].

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