EV Battery Cooling: Effect of Fin Spacing

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Abstract: The battery thermal management system plays a vital role in the control of the battery thermal behavior. The BTMS technologies are: air cooling system, liquid cooling system, direct refrigerant cooling system, phase change material (PCM) cooling system, and thermo-electric cooling system as well as heating. The thermal management of electric vehicle (EV) batteries plays an important role in ensuring that the batteries operate within a safe range. Therefore, the liquid cooling method was used to design and fabricate an effective thermal management system. In this experiment, a heater block was used as a heat source in place of the actual battery, while a heater power of 300 W was used as the heat load. At this heat load, the surface temperature of the aluminium block could reach up to 200 ˚C. The lowest heater surface temperature of 44 ˚C was achieved by using a liquid cold plate with a fin spacing of 2.0 mm, whereas the highest heater surface temperature of 54 ˚C was achieved by using a liquid cold plate with a fin spacing of 4.0 mm. Based on the surface temperature of the heater for the three different liquid cold plate fin spacings, the battery managed to operate within the permitted working temperature of below 50 ˚C.

Keywords: EV, battery thermal management, liquid cooling, heat transfer, liquid cold plate, fin spacing, oblique fin, battery.

Introduction:

Batteries play an important role in powering all types of electric vehicles. Nowadays, there is a growing demand for lithium-ion batteries in various applications, particularly for electric vehicles, which require a more reliable battery management system for controlling the battery packs. Due to their high energy[1] density, low self-discharge rate and long cycle life, lithium-ion batteries are the main source of power in electric vehicles. The thermal safety [2]of lithium-ion batteries during their application has become a main issue. In the past few years, researchers and automotive manufacturers have been focusing on the cooling of Li-ion batteries as this is a major obstacle in the development of electric vehicles.

When the battery is operated at a low temperature, the power output will be reduced due to the suppression of the electro-chemical reactions, while a high temperature [3]will accelerate corrosion, thus leading to a reduced battery life. Other than that, the temperature range and uniformity in a pack are significant factors for obtaining optimum performance from an EV battery pack. It is necessary to introduce a cooling method for the Li-ion battery to ensure that it has an effective thermal[4] management system. There are several types of cooling methods for Li-ion batteries such as air cooling, liquid cooling and the use of phase change materials.[5] Air cooling is widely used as a cooling method in order to ensure that the Li-ion battery is safe, reliable and has a long operating life. In addition, temperature uniformity in the battery module can be improved by using the air cooling method. This method has its limitations, and it is suitable for a low energy density Li-ion battery. If the battery has a high energy density, then a liquid cooling system provides the most effective thermal management[6], a good thermal management

system must be able to maintain the temperature of the battery within a suitable range without over-designing or limiting the performance of the battery. Therefore, a heat transfer augmentation scheme is used to overcome this problem. compared the heat transfer performance of a conventional straight channel liquid cold plate with that of an oblique fin liquid cold plate. They found that the heat transfer coefficient of liquid water through the oblique fin channel is higher than that of the straight channel, especially at high flow rates. Besides that, the channel width of the mini channel also affects the heat transfer performance. The heat transfer performance can be increased by decreasing the width of the mini channel. In addition, the heat transmission rate can be maximized by choosing the optimum fin spacing. The fin surface can be increased by diminishing the fin spacing, thus enhancing the rate of heat transfer. The main objective of this paper was to investigate the systematic effect of liquid cold plate geometries (by diminishing the fin spacing) with ethylene glycol as the coolant [7]hfluid on the surface temperature of batteries and to identify the potential of liquid cold plate geometries in reducing the high generation of heat (up to 200 ˚C) in batteries to a safe operating temperature of within 50 ˚C.

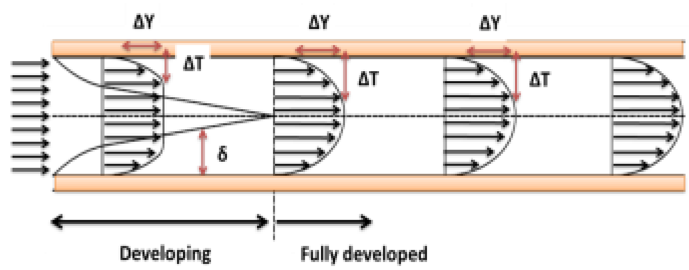

Fig.1: Boundary layer development for conventional straight channel

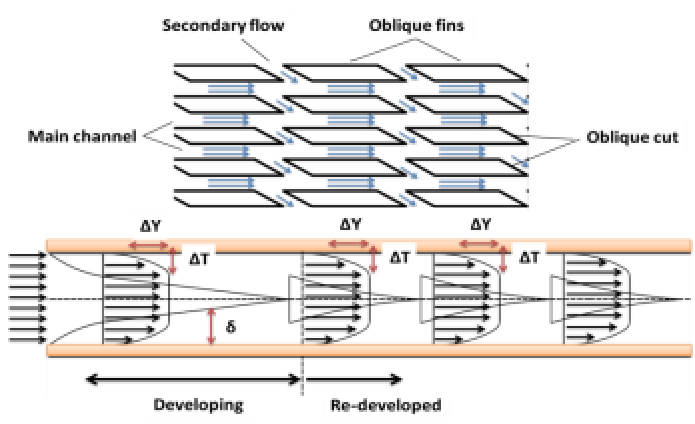

Fig.2: Boundary layer development for oblique fin channel

Design:

The oblique fin cold plate is a highly efficient piece of equipment designed for the cooling of Li-ion batteries. The oblique fin significantly enhances the transfer of heat using a low power pump compared to a conventional straight channel with similar channel and fin dimensions. The improvement was made possible by introducing oblique slots on the straight fins. This segmentation changed the flow conditions in the channel. It can be seen that the segmentation of the continuous fin into sectional oblique fins-

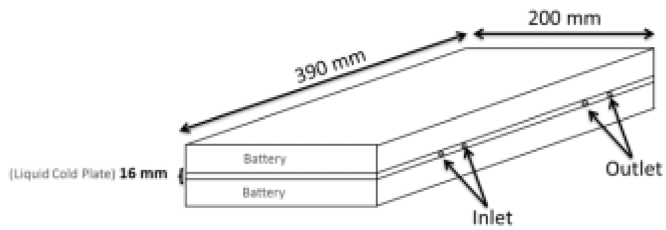

Fig.3. External dimension of liquid cold plate

-disrupted the flow path. This discontinuation of the downstream fin caused the hydrodynamic boundary layer development to restart at the leading edge of the next downstream section. The oblique fin was much shorter compared to the long continuous fin of the conventional mini channel, thus effectively limiting the development of the boundary layer. This was unlike that of the straight channel, which exhibited a decreasing trend along the flow direction. The thickness of the cold plate was 16 mm and it was stacked between two modules of batteries. Thus, the cold plate will occupy less space when it is installed in a vehicle. Other than that, the side of the cold plate was designed with two holes for the-

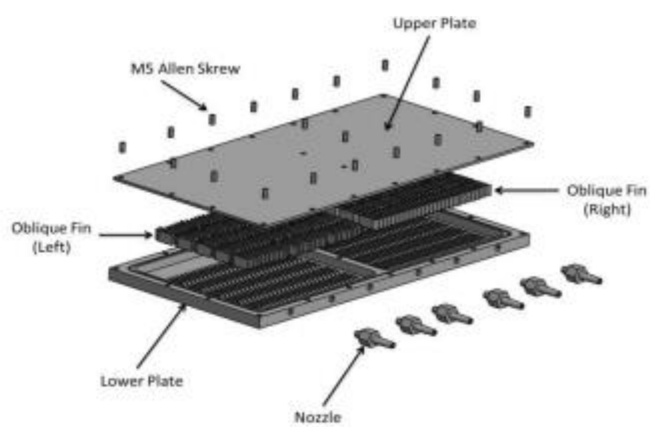

Fig.4: Schematic diagram of liquid cold plate assembly

-coolant flow inlet and outlet. The pump was operated at a low power because the inlet and outlet were at the same level. The cold plate had two individual plates, an upper plate and a lower plate. Both plates had a similar shape but different designs. The upper plate was designed as a cover for the lower plate, while the lower plate formed the main part of the liquid cold plate because all the oblique fin channels were placed in this part, as shown in Fig. All the parts of the cold plate were produced by using a

Computer Numerical Control machine. The upper and lower parts were joined by an M5 skew. The configuration and dimensions of the oblique structure are shown in fig.

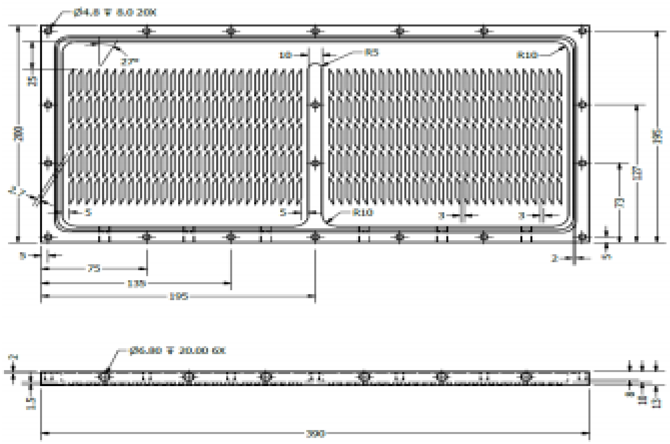

Fig.5: Configuration and dimensions (mm) of oblique structure

Result:

The temperatures were measured by 4 thermocouples placed at different locations. As shown in Fig. 8, the temperature of the heater started to increase when the heater was switched on, until at a certain time the temperature became constant and the maximum temperature of the heater was reached. The Li-ion battery experiences thermal runaway when the temperature of the battery increases above 120 ˚C. Therefore, the working temperature of the battery was maintained within the permitted limit of 50 ˚C by using a liquid cold plate. Vortex was created near the bottom inlet. The average velocity of the entire passage is 1,026 m/s. Figure 4(b) shows the result of the Stream Line model with 10 air guide fins. A lot of vortexes were formed near the air guide, and the average velocity through the entire passage, with the opposite direction of flow.

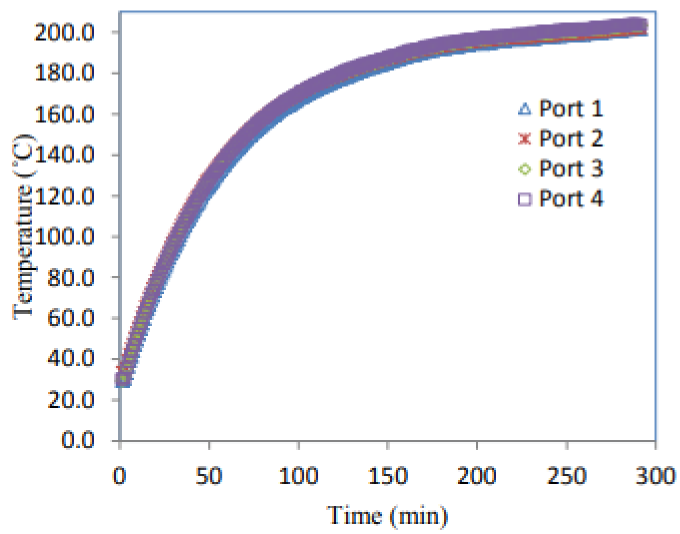

Fig.6: Transient response of tested heater

Fig.7. shows the drop in the temperature of the coolant at the inlet and outlet. The temperature drop was influenced by the flow rate for all the three liquid cold plates. By increasing the flow rate, the drop in the temperature of the coolant at the inlet and outlet was reduced. The highest temperature drop of 17 °C at a flow rate of 0.6 LPM resulted when the 2.0 mm fin spacing was used. Therefore, a liquid cold plate with a fin spacing of 2.0 mm is the most reliable and safe plate for use in batteries operating in conditions of high heat generation. Vortex was created near the bottom inlet. The average velocity of the entire passage is 1,026 m/s.

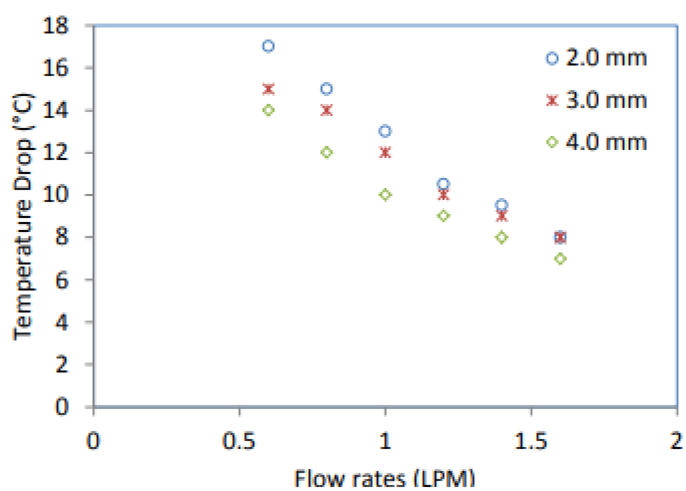

Fig.7: Comparison of temperature drop with flow rate

Conclusion: Three different liquid cold plates with fin spacings of 2.0 mm, 3.0 mm and 4.0 mm were investigated for effective and efficient thermal management in high heat generating batteries[8]. At a heat load of 300 W, the lowest heater (battery) surface temperature of 44 °C was achieved by using a liquid cold plate with a 2.0 mm fin spacing at a flow rate of 1.4 LPM. Hence, the heater surface temperature can be decreased by diminishing the fin spacing and by increasing the coolant flow rate. Therefore, it can be concluded from this experiment that the liquid cold plate geometries and the volumetric flow rate can influence the transfer of heat.

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