Air flow and cooling analysis for Li-ion battery

Mr. Rahul Yadav, Dept. of Electrical Engineering

Dr. C.V. Raman University, Bilaspur

Abstract: This paper presents air guide fin on battery module with air cooling system that is used on electric vehicle and used forced convection in order to study the consequent of air flow and cooling effect. The number of air guide fins[1] was increased from 5 to 120 in order to conduct comparative analysis on the relationship between average temperature and average flow velocity of the entire battery cell according to number of air guide fins. The result analyzed the line of air flow in battery cooling channel, compared average temperature of the entire battery cell by the number of air guide fins, and compared the standard deviation of average temperature of each battery cell by the number of air guide fin. The number of air guide fins increased from 5 to 120 in order to conduct a comparative analysis of the relationship between the average temperature and the average flow velocity of the entire battery cell.

Keywords: Cooling Channel, Electric vehicle, Lithium ion Battery, Battery cooling system, Air guide fins.

Introduction:

As a high capacity battery is discharged upon use, the temperature of the battery rises. If this battery goes out of an appropriate range of temperature, it causes reduced battery performances, risk of explosion, and reduction of battery life. Various cooling methods have been suggested and studied in order to change the heat[2] produced from the battery cell to an appropriate operation temperature. According to cooling solvent, cooling method is divided into liquid cooling method and air cooling method. Since an electric vehicle produces power from electricity unlike a vehicle with internal combustion engine, high-capacity battery is critical. We studied the advantages of air cooling method over liquid cooling method in removing the heat at the end of the fin in a fin cooling system[3]We studied three dimensional transient thermal analysis[4] of an air-[5] module that contains prismatic Li-ion cells. We have conducted theoretical analysis by changing the arrangement of the previous battery design for forced air cooling .[6]Tao Wang et al. investigated lithium-ion battery module with different cell arrangement structures and forced air-cooling strategies.[7] Developed of efficient air cooling strategies for lithium-ion battery module based on empirical heat source model. While many studies were conducted, there was no previous studies analyzed cooling effects by installing guide fins at cooling channel in the battery module with air cooling method. This studied use CFX, a computational fluid dynamics software used for flow analysis, to quantitatively verify the flow of fluid inside the battery module that includes air guide fin, the air flow regarding the number of air guide fins, and the cooling effect of battery cell.

MODEL ANALYSISAND CONDITIONS:

According to the type of flow upon cooling using forced convection in a battery cooling system, turbulent flow occurs at the battery cooling inlet and outlet, the speed at the axial direction decrease on the boundary when passing the narrow cooling passage between batteries, and the speed gradually accelerates at the center of the passage to go through transition to laminar flow.

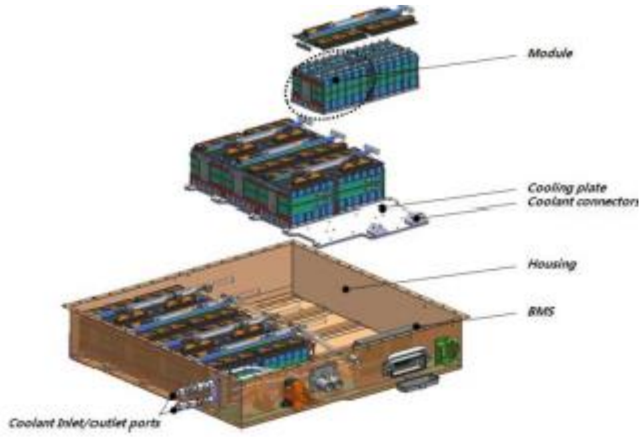


Figure 1. Configuration of Battery Pack System.

In order to simulate this using a computational fluid dynamics program, each of the analysis area needs to be separated and the grid of cooling passage between batteries need to be created very closely, but such tasks require sharp increase in analysis time. Since this paper focuses on cooling effect of battery module, it used SST turbulence model, one of the turbulence models with high accuracy of analysis on wall heat transmission. A few assumptions are required in analyzing cooling effect. Battery module and the outside are all insulated except the outlet, and the wall is assumed to be no-slip.

MODELING: The form of the battery module subject to analysis is a stack of 5 pouch-type lithium ion battery cells. The dimension of each cell is 130*240*6.5mm3 (Width*Height*Thickness), and each cell is covered with aluminum heat sink. The gap between battery cells is 2mm. The gap of air guide fin is different by the number of fins, and the length of the gaps is all the same. To reduce analysis time, only half of the battery module was modeled with symmetric conditions. The form of the modeling is shown.

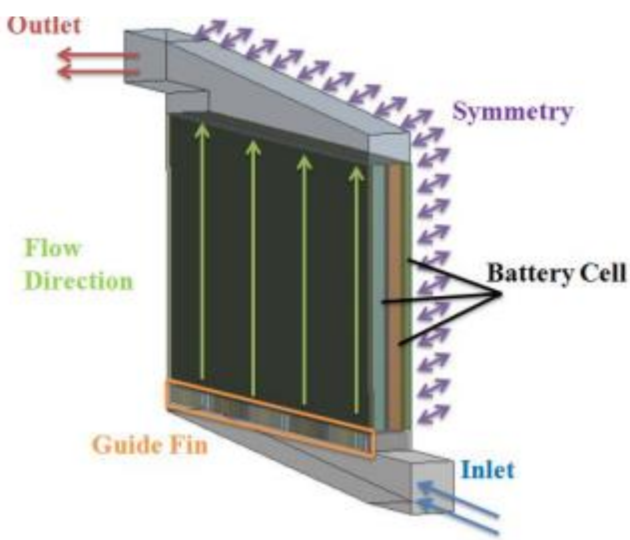


Figure 2(a). Configuration of Battery Module Analysis Model.

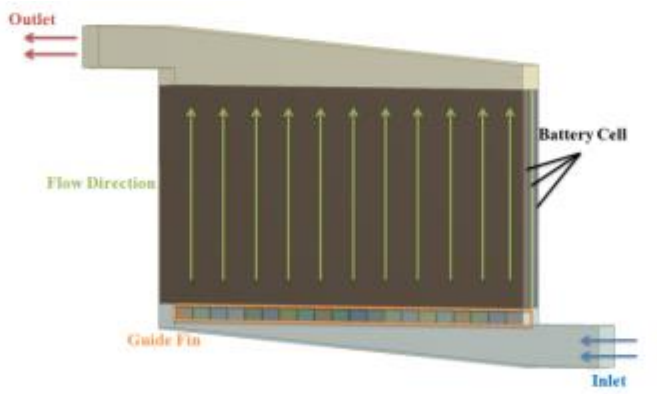
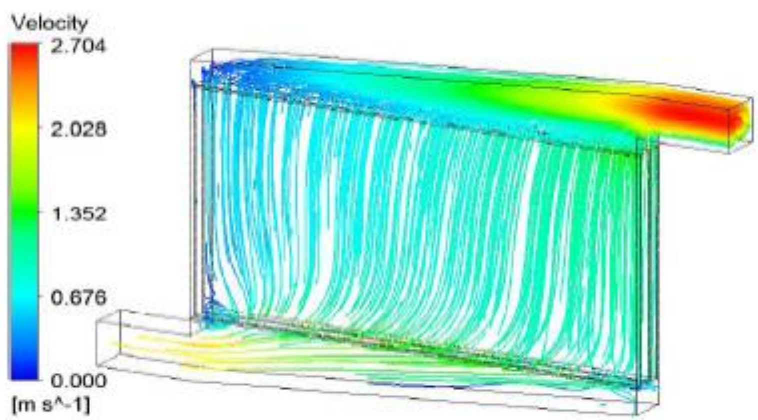


Figure 2(b). Configuration of Battery Module Analysis Model.

Grid generation: The number of guide fins for the battery model is different by analysis model, leading to slight differences in the number of factors and nodes. Dense grids were generated in the parts where cooling passage and battery cell meet. Also, due to high number of guide fins, the model with 120 fins, where the gap between fins is smaller than 1mm, generated denser grids near the guide fins.This study copied the situation where the air in battery module is discharged from the inlet of the cooling passage, where cooling fan is operated, through cooling passage to the outlet. The initial temperature [4]of each battery cell that composes the battery module was set as 298.15K, which is equal to the outdoor temperature, and the caloric value per unit volume was set as 100,000W/m3.The heat transmission coefficient forced convection was set as 10W/m2 K. The temperature of cooling passage was also set as 298.15K. Fluid analysis at abnormal condition from 0~600 seconds was conducted by setting the pressure inside and outside as the air pressure (1atm) and the wall as no-slip condition. Flow velocity at inlet was set as 2m/s. and relative pressure condition at outlet was set as 0Pa.



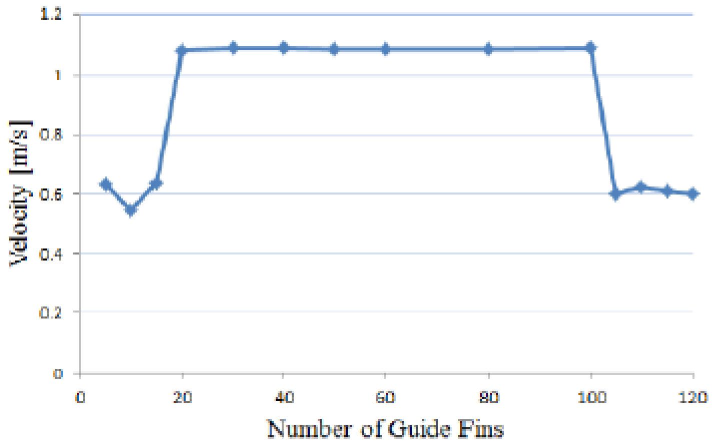


Figure. Comparison of Average Velocity by Number of Guide Fins in All Cooling Channels

Result: Different plates fins spacing of 2.0 mm, 3.0 mm and 4.0 mm were investigated for effective and efficient thermal management in high heat generating batteries. At a heat load of 300 W, the lowest heater (battery) surface temperature of 44 °C was achieved by using cooling fins. 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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