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Multiple Channel Heat Exchanger Simulation in Lithium Ion Batteries

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ABSTRACT: Research work is carried out design the lithium ion battery with heat exchanger embedded in the system to remove the excess amount of heat generated during the transfer of the charge. Six heat channels were implemented in the design to remove the heat. Water is used as the coolant in the model. Velocity and pressure components in all the designated channels were computed for the flow of coolant and also the heat distribution over the model.

Keywords: FEM, LIB, Heat Exchanger, Channel

I. INTRODUCTION

Advancement of the technologies ranging from portable electronic system to fuel efficient vehicles depends upon the power offered by the batteries. Nowadays various rechargeable batteries are available in market, among them lithium based batteries attained a highest position in various aspects such performance, durability etc. Various features of Lithium-Ion-Batteries (LIB) are excellent power and energy density, no memory effect, high rate of power discharge, and broad temperature range of operation. LIB in small size having dimension of AA-size are widely used to power small portable electronic devices which provide high voltage greater than 4.0 V and high energy density ~265 (Wh)L-1. LIB have 4-5 times higher power density than lead acid batteries, but thermal stability problem must be overcome [1].

Heat accumulation inside the battery is the main concern. Heat generated in the cell if not removed sufficiently may cause the rise in cell temperature. This may lead to the cell failure accompanied by ignition of battery active material. Therefore battery thermal management is the main factor determining its performance, life, and safety. Irreversible process of ohmic heating caused by current transfer across internal resistances and from reversible entropy heat change from cell electrochemical reactions causes the generation of heat in batteries. Thermal management in the batteries are done using forced air cooling and liquid cooling using water-glycol based coolants.

Computer based simulation has been done to design thermal management models for LIB and there optimization has been done. This field has been researched and many models has been purposed, for example, one-dimensional thermal model [2-3], which are extended to design three-dimensional models [4-7]. Also the coupled electrochemical models [8-11] were developed to study the heat transfer and thermal management.

In this research paper three dimensional model of LIB has been developed using finite element method (FEM) based tool to give better insight of heat removal implementing liquid coolant.

II. THREE DIMENSIONAL MODEL

FEM based approach is used to model the multiple channels heat removal model of LIB utilizing water as coolant. Structural dimensions of having length of 10 cm, width 10 cm, and thickness of 0.6 cm are taken for the battery. It consists of three functional blocks: battery section, cooling fins, and 6 channels acting as heat exchanger. The heat exchanger channels are having width 0.2 cm and thickness of 0.08 cm. LiPF₆ is used as electrolyte and electrodes Li_xC₆ (cathode) and Li_xMn₂O₄ (anode) are used in the simulation. Cooling fins are taken to store the fluid to pump in the channel heat exchanger having dimensions of length 9.6 cm, width 0.8 cm, and thickness of 0.6 cm. Design layout of the structure created in software is shown in Fig. 1.

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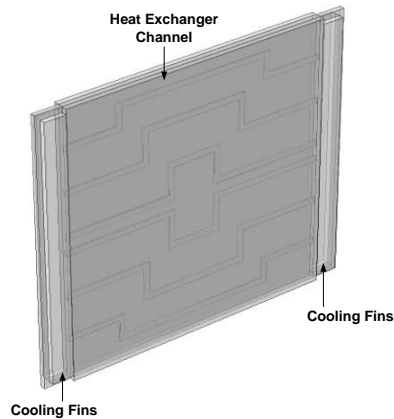


Fig. 1 3D view of the design LIB.

After designing the layout of the battery with channel heat exchanger, meshing of the model is done with predefined element size of coarse. Figure 2 shows the mesh of the designed LIB model. After generating the mesh of the model, system was computed for fluid flow and temperature change in the model.

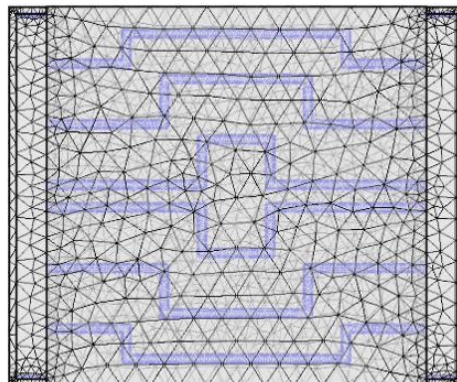


Fig. 2. Mesh formation of the model

III. RESULTS AND DISCUSSION

Thermal models of the designed LIB battery simulate for temperature profiles inside the battery cell during charge and discharge. Channel path is designed inside the battery to circulate the fluid as coolant to remove the generated heat is shown in Fig. 3.

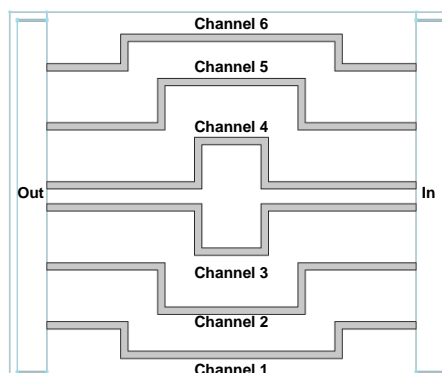


Fig. 3 Channel layout in LIB model.

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Velocity and pressure of the fluid inside the channels are computed in the simulation. Fluid movements i.e. velocity and pressure in the channel for water as fluids in all channel are given in the Table 1 and Table 2 respectively. Figure 4 shows the velocity of the coolant in the LIB model. Figure 5 shows the velocity of coolant entering the various channels and velocity at the outlet of the respective channels.

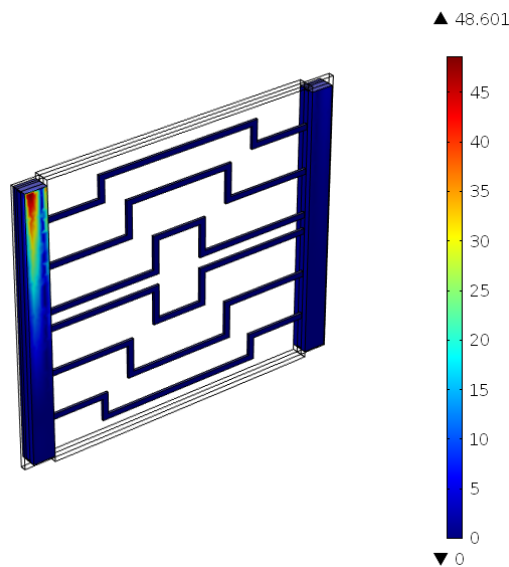


Fig. 4. 3D view of velocity at the outlet cooling fin.

Table 1. Fluid velocity in channel.

Channel	In Fluid Velocity (ms ⁻¹)	Out Fluid Velocity (ms ⁻¹)
1	32.05029	37.99684
2	31.34559	38.02624
3	34.82747	38.09952
4	33.80813	38.04209
5	30.23035	37.45831
6	31.40259	37.76753

Table 2. Fluid pressure in channel.

Channel	In Fluid Pressure(Pa)	Out Fluid Pressure(Pa)
1	-4.09E+06	-7.15E+05
2	-4.11E+06	-7.13E+05
3	-4.13E+06	-7.33E+05
4	-4.11E+06	-7.50E+05
5	-4.12E+06	-7.46E+05
6	-4.13E+06	-7.78E+05

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Figure 6 shows the 3D graph of the pressure in the various section of the LIB model. Figure 7 shows the thermal gradient in the LIB model.

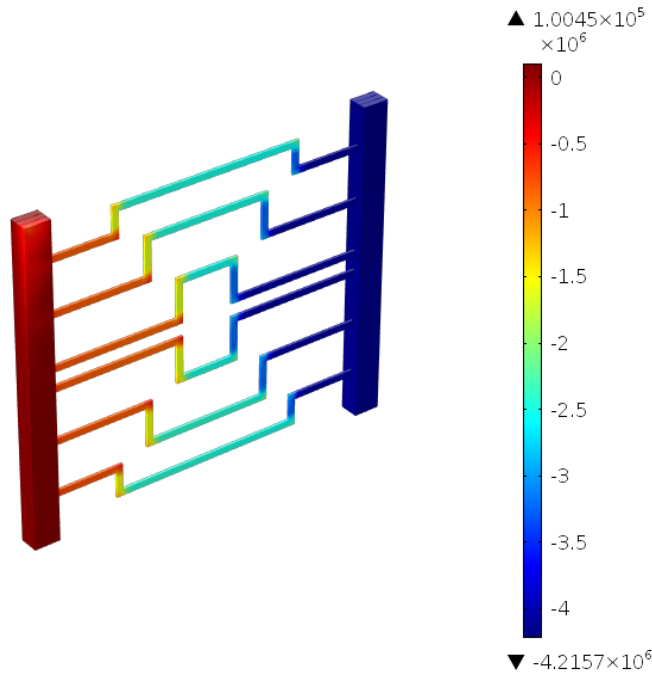


Fig. 6 Pressure (Pa) of coolant in LIB model.

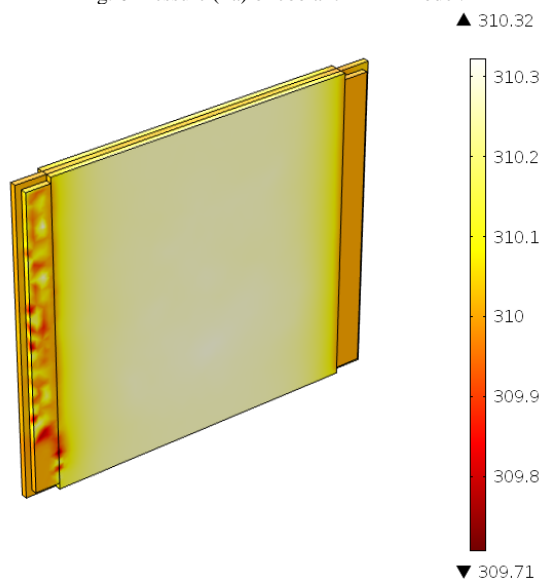


Fig. 7 Heat removal from LIB model.

IV. CONCLUSION

The research work is carried out to simulate the LIB model with six heat exchanger channels to remove the heat from it. Water was used as coolant in the channel. Velocity and pressure components of the coolant in all the channels were



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computed. Also the thermal variation on the surface of the LIB is computed. It is seen that the LID model shows prominent results which can be implemented to design the small LIB with heat exchangers.

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