Analysis of liquid cooling and heat dissipation systems for lithium-ion battery packs

R. A. Soto Ortega, J. R. Ramírez Razo, V. H. Tovar Jasso

Universidad de Guanajuato, División de Ingenierías Campus Irapuato-Salamanca.

Abstract

In this study, a heat dissipation system for cylindrical lithium-ion battery packs is evaluated by comparing a proposed cooling channel with the heat dissipation capabilities of a serpentine cooling channel and a U-shaped cooling channel in a battery stack. The proposed cooling channel adopts a serpentine design that includes an additional pathway through the battery stack, thereby enhancing heat exchange with the batteries.

In the second configuration, the channel was bifurcated into two tributaries, alternating fluid inflow in one with outflow in the other, resulting in a countercurrent configuration.

Utilizing Ansys Fluent for simulation and analysis, we confirmed that the proposed design offers superior heat dissipation performance, attributed to the increased contact area.

Introduction

Nowadays, the demand for electric vehicles has increased due to fuel prices and air pollution caused by fuel vehicles. Electric vehicles have become a promising solution, being potentially more environmentally friendly if the energy used to charge them is produced by renewable sources. One of the main problems with this technology lies in the batteries. The optimal working temperature for a lithium-ion battery is between 20–45 °C [1]. The heat generated by the battery increases degradation, reducing its lifetime. That's why a stable and efficient cooling and heat dissipation system for the lithium battery pack in electric vehicles is very important. The thermal management of the battery packs has become essential for efficiency and effectiveness for this application [2].

Methodology

The methodology used in this work is based on the research done by Huanwei Xu y Xin Zhang [1]. A structural design of the cooling and heat dissipation system is proposed, consisting of water flow in a channel, acting as coolant to dissipate the heat generated by the batteries. The following considerations are made: the battery is isotropic, the convection and thermal radiation inside the battery is ignored, the heat capacity of the battery is constant and independent of time. The volumetric heat generation by the batteries is 74163 W/m3. The model number of the batteries used in this work is the 18650 Li-ion rechargeable battery. The geometry consists of a battery pack of 40 batteries. The base model is shown in Figure 1.

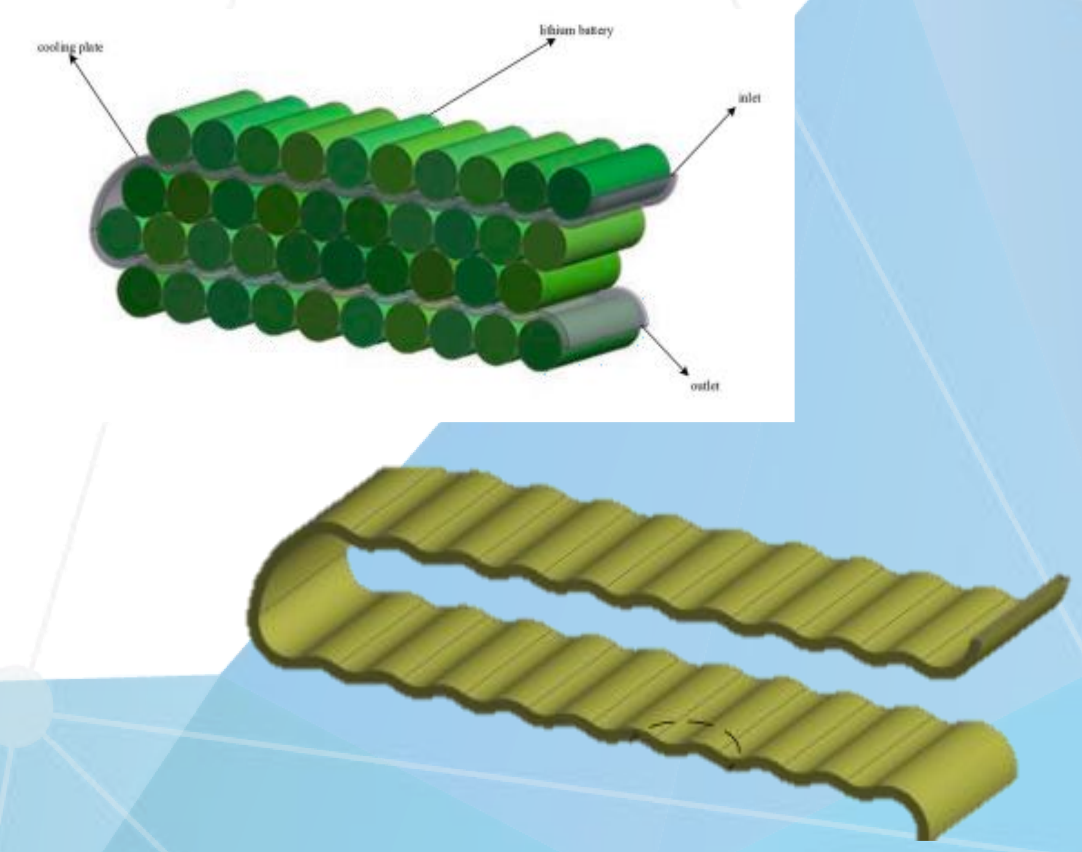

Figure 1. Reference serpentine heat dissipation model.

The first geometry proposed to improve heat dissipation in the battery pack is shown in Figure 2. The mesh generated in Ansys Meshing for this case is shown in Figure 3.

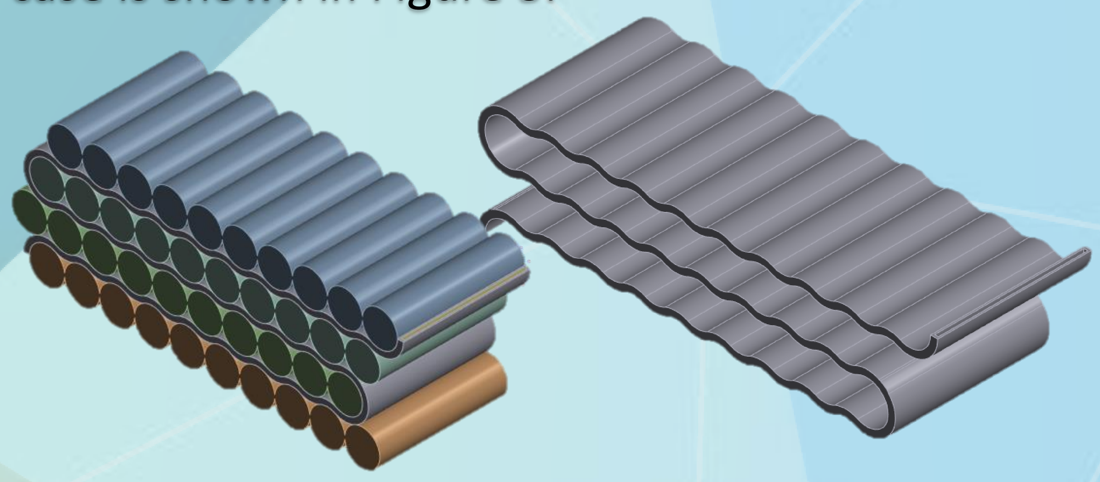

Figure 2. Propuse serpentine heat dissipation model.

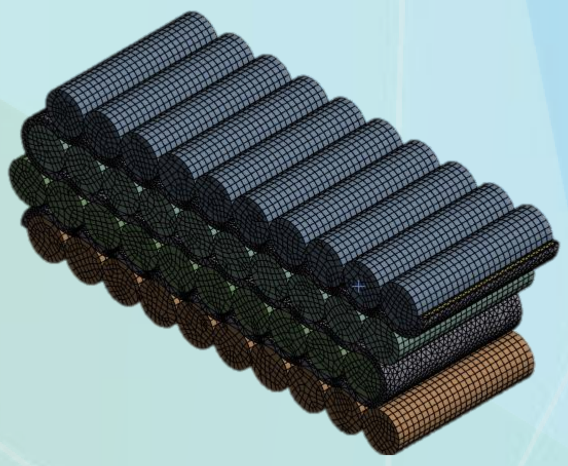

Figure 3. Propuse serpentine heat dissipation model in mesh.

The second proposal to improve heat dissipation, consisting of counterflow channels, is shown in Figure 4. The mesh for this geometry is shown in Figure 5.

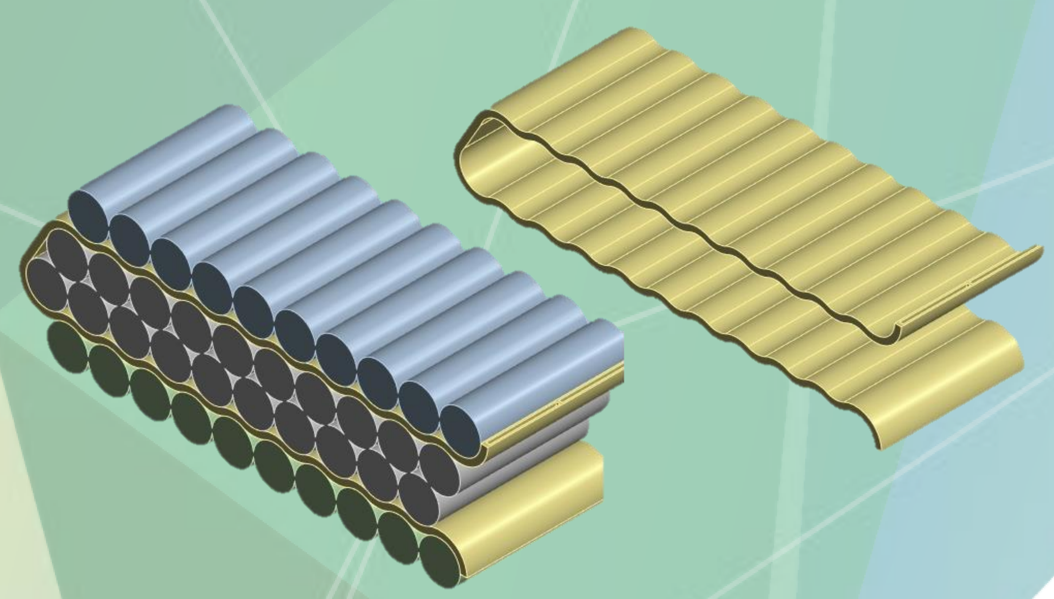

Figure 4. Proposed counterflow heat dissipation model.

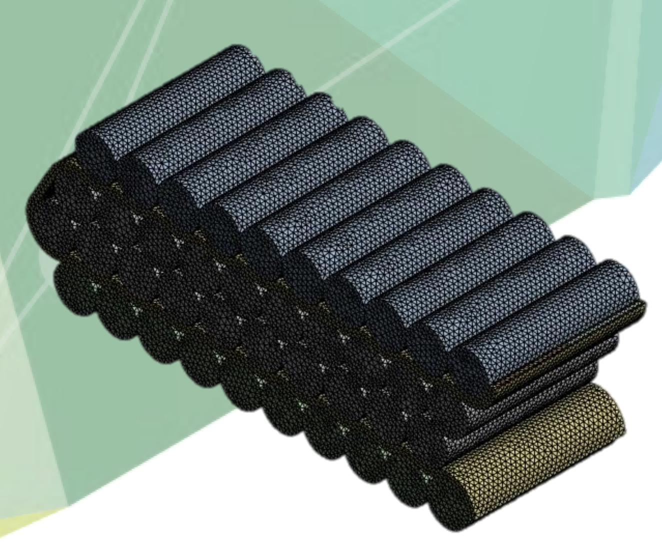

Figure 5. Meshing of the proposed counterflow heat dissipation model.

Results and discussions

In the first model, which follows a longer path across all batteries, the resulting temperatures show a lower overall temperature, with an average value of 302 K (Figure 7a). However, this model exhibits a notable hot spot in the bottom right corner of the battery, with a maximum temperature in the lower right battery reaching 310 K. It is evident that this battery has limited contact with the channel, hindering its ability to dissipate heat effectively.

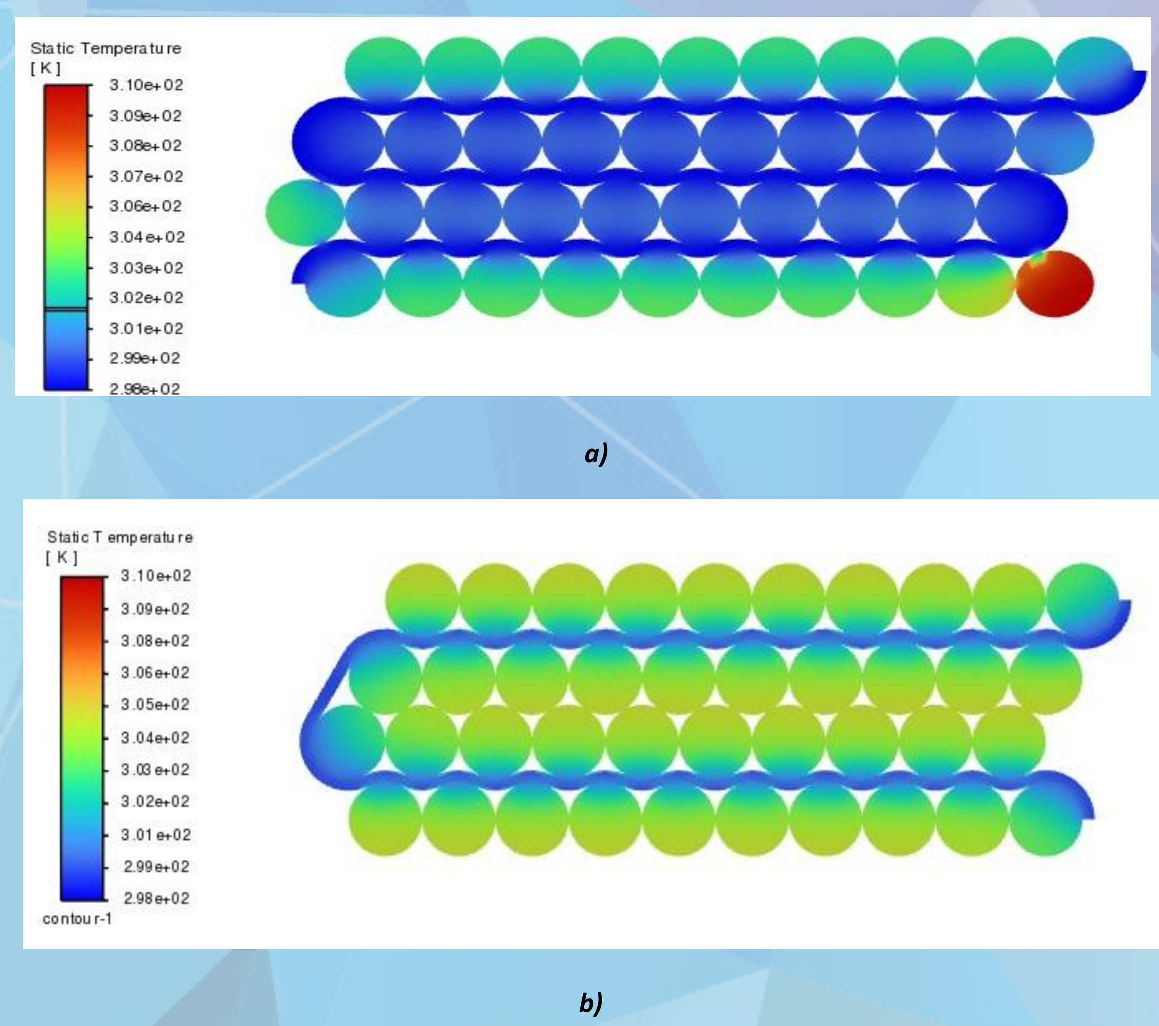

Figure 7 Temperature distribution diagram of the proposed models.

In the second model (Figure 7b), the temperature distribution appears to be more uniform; however, it does not reach an overall lower temperature than the first geometry, with an average temperature of 304 K in the batteries.

Conclusions

Both proposed configurations demonstrate improvements over the original design. In the first configuration, the temperature distribution is more homogeneous, with battery temperatures reaching 298 K, and only one hot spot with a high temperature of 310 K. However, in the counterflow configuration, the heat distribution is suboptimal, as the average temperature remains at 304 K. It is important to note that the last battery in the stack of the first proposal increases in temperature because it has the least contact area. For future analysis, we can further improve this proposed geometry by making the contact area of all the batteries more homogenous.

References

[1] Qian, X., Xuan, D., Zhao, X., & Shi, Z. (2019). Heat dissipation optimization of lithium-ion battery pack based on neural networks. Applied Thermal Engineering, 162, 114289. https://doi.org/10.1016/j.applthermaleng.2019.114289

[2] Xu, H., Zhang, X., Xiang, G., & Li, H. (2021). Optimization of liquid cooling and heat dissipation system of lithium-ion battery packs of automobile. Case Studies In Thermal Engineering, 26, 101012. https://doi.org/10.1016/j.csite.2021.101012