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ANALYSIS OF THERMAL MANAGEMENT SYSTEM OF CYLINDRICAL LITHIUM ION BATTERIES IN ELECTRIC VEHICLES

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Abstract

Lithium-ion batteries are found suitable for hybrid electric vehicles (HEVs) and clean electric vehicles (EVs), and temperature control for lithium batteries is essential for long-term performance and longevity. Unfortunately, battery thermal management (BTM) was not given much attention due to misunderstandings of battery temperature behavior. The design of the battery temperature equity is important. The uniformity of the temperature of the lithium battery pack is critical to the performance and life of the lithium battery system. The uneven distribution of temperature can easily lead to a heat escape from the lithium battery pack, which could pose safety hazards for the electric car. Temperature similarity is usually measured with Maximum Temperature Difference (MTD). This paper aims to design a cooling system for battery packs with good temperature similarity. In this project, two battery temperature control solutions are selected and analyzed: a wavy cooling channel and a U-shaped cooling system is used. The results show that the wavy tube cooling system has a better cooling effect.

1. INTRODUCTION

Transportation has become the world's largest consumer of petroleum products, accounting for 49% of oil. The efficiency of fuel consumption in cars is very low, so efficient transportation strategies will help to reduce unnecessary energy consumption without providing additional services. One of the newest energy saving ideas is the promotion of clean or green energy vehicles. Great attention has been given to hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and clean electric vehicles (EVs) as other possible ways to reduce carbon emissions in transportation. These vehicles are said to provide solutions to greenhouse gas emissions, provide better use of new energy sources, and benefit from long-term energy savings. More importantly, opportunities are being offered to EVs, as the US government provides $ 2.5 billion in grants and subsidies to various EV-related companies, and China is shifting its focus on developing EV economic and energy policies. The biggest challenge is for clean energy vehicles to be sold to save electricity. Building a good car battery pack for high performance is important. Charged lithium-ion batteries are well suited to HEVs and EVs, but have not yet been widely accepted in the automotive industry due to obstacles such as cost, safety, and low temperature performance associated with the effects of temperature. Thermal battery management (BTM), which is a critical issue in the development of clean electric vehicles, has received little attention over the past few years due to understanding the thermal properties of lithium-ion batteries.

2. LITERATURE REVIEW

Huanwei Xu et al. (2021) developed a proposed development design framework to minimize the maximum temperature difference (MTD) of a car lithium battery pack. First, the cooling channels of the two cooling and exhaust systems are analyzed: the serpentine cooling system and the U-shaped cooling system. The results show that the serpentine cooling system has a better cooling effect. Second, a flexible combination of acquisition models based on advanced particle development algorithm is proposed to assist in the optimal design of the serpentine cooling system. The development results show that the proposed framework can solve the problem of explicit development with small samples and find a complete global solution and avoid falling into the top local solution. However, this paper only uses a flexible combination of surrogate models to make a significant temperature difference. Considering the multi-purpose features of the lithium battery pack, a multi-purpose design based on a flexible acquisition model is a future study.

Seyed Mazyar Hosseini Moghaddam (2019) has developed four battery temperature control solutions using Computational Fluid Dynamic (CFD) simulations. Imitation results show that direct liquid cooling has excellent cooling efficiency as it has a very close contact with cells and high temperature. The downside to direct liquid cooling is the complexity of the design due to its leaking capacity. The soluble liquid needed for this type of cooling is very expensive. Indirect cooling methods (tube cooling and floor cooling) have moderate performance. In contrast to air cooling, the distribution of temperature in a module can be easily controlled as the coolant is connected to the temperature by all cells in the same way. Comparisons between the two indirect methods show that cooling the tube creates a lower cell temperature, however, lower cooling has a simpler design.

Zhiguo Tang et al. (2019) performed a three-dimensional (3D) simulation of a multi-channel wavy tube in a liquid lithium-ion battery cooling module, and numerical adjustments were made by varying the wavy connection angle and wavy tube weight flow rate of multiple channels. The increase in wavy contact angle and the flow rate of the bulk positively affect the efficiency of heat dissipation and the homogeneity of the temperature field of the battery module. From the output, the maximum temperature and temperature difference of the battery areas in the module decreases at the end of the discharge and increases the wavy contact angle and the maximum flow rate.

Thomas Imre Cyrille Buidin and Florin Mariasiu (2021) conducted research on the type, design and operating principles of BTMSs used in the manufacture of multi-structured Li-ion batteries, with a focus on cooling technology. The advantages and disadvantages of each component, as well as the proposed BTM solutions, are widely investigated, regarding the compatibility of these systems in different Li-ion battery conditions. The integrated information thus provides the necessary and important information and suggests future research guides for those interested in this topic to be used to increase the efficiency of battery temperature control systems.

3. METHODOLOGY

To remove the heat of the lithium battery, two channel cooling structures are introduced. The first type of cooling and heat dissipation is a wavy cooling system. The second type of cooling and exhaust is a U-shaped cooling system. Lithium battery used in this analysis cylindrical battery, the battery model is 18650 diameter and the height of one battery is 18 mm and 65 mm respectively. Aluminum cooling plate material. For comparative thermal simulation analysis and simulation, the number of inlets and exits of the two structures are the same. That is, the number of entry and exit is 1, respectively. In addition, the size of the cooling plate and the cooling wall of the two design systems are kept the same, that is, the thickness of the cooling plate is 3 mm, and the thickness of the cooling wall is 0.7 mm. The number of batteries in the wavy cooling system is 45 and 40 in the U-shaped cooling system. The meshing is made with ANSYS Fluent. Battery pack models are separated using tetrahedral mesh.

Material	p(Kg/m^3)	C(J/KgK)	k(W/(mk))	μ(Kg/(ms))
Water	998.2	4128	0.6	1.003 x 10^{-3}
Aluminium	2719	891	202.4	-
Battery	2018	1282	2.7	-

Table 1.Thermal physical parameters of materials for cooling and heat dissipation system.

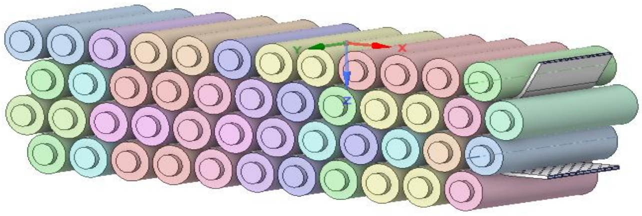

Fig.1 3D model of wavy cooling channel battery pack.

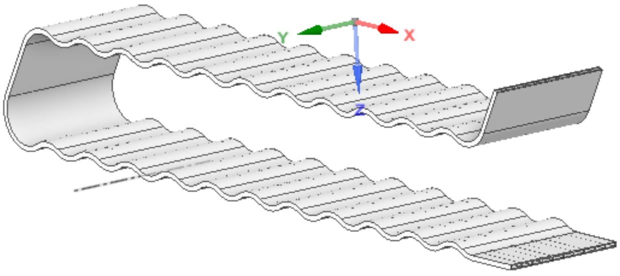

Fig.2 3D model of wavy cooling channel.

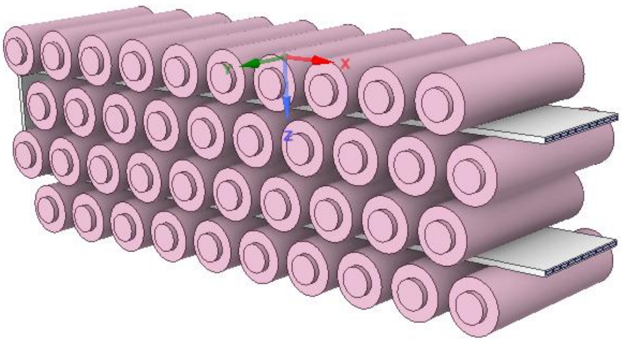

Fig.3 3D model of U-shaped cooling channel battery pack

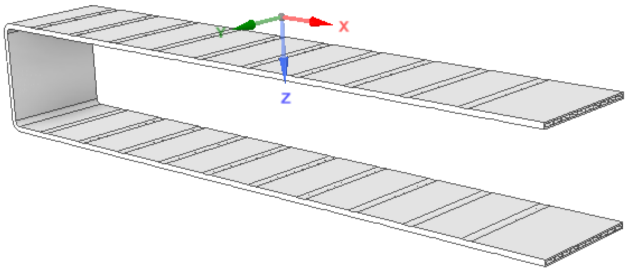

Fig.4 3D model of U-shaped cooling channel.

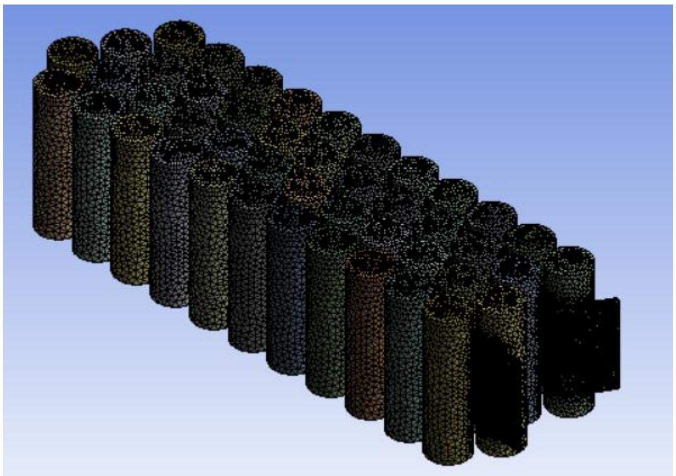

Fig.5 Mesh model of wavy cooling channel battery pack.

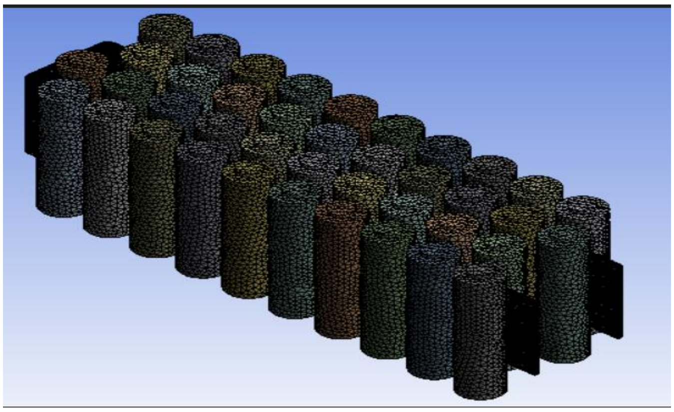

Fig.6 Mesh model for U-shaped cooling channel battery pack

4. BOUNDARY CONDITION

After the meshing is completed, the next step is to set the boundary conditions. The cooling temperature at the entry point is set as 25 ° C, the flow rate of cooling fluid is set at 0.002kg / s. The most important boundary condition is to set the heat source. Lithium battery pack is considered a source of heat for the same body. In comparison, the discharge rate of lithium battery is set as 4C i.e., the volumetric heating generation is 74163 W / m3. In this process, the voltage is a constant value, so the current is also a continuous value, which ensures a continuous voltage and a continuous current of the test.

Discharge rate	Volumetric heat generation (W/m3)
1C	5318
2C	19452
3C	42400
4C	74163

Table 2.Body heat generation rate under different discharge rates of lithium batteries.

5. RESULT

Under conditions of uniform flow rate, cooling temperature, flow rate cooling channels are measured and analyzed. Figure 7 shows the temperature distribution of a lithium battery pack after a hot analysis of the cooling channels of two different structures.

It can be seen in Fig. 7 that the maximum temperature of the wavy cooling system is 40.684 ° C. The MTD of the wavy cooling system is 15.321 ° C. The heat released by the lithium battery will be absorbed by the coolant. , and the cooling temperature gradually rises from the point of entry to the exit point. The high temperature of the lithium battery pack comes from source of the battery. It is evident in Fig. 8 that the maximum temperature of the U-shaped cooling system is 43.552 ° C, the MTD is 18.21 ° C, and the cooling inlet is also at a low temperature, as well as cooling temperature. gradually rising from the entrance to the exit, the effect of simulation is real and reliable.

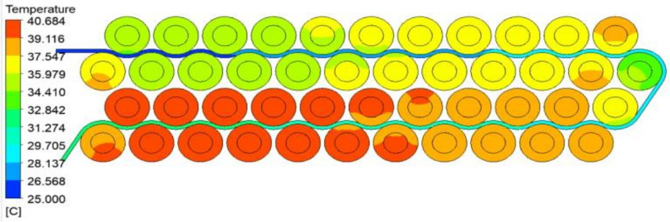

Fig.7 Temperature distribution result of wavy cooling channel.

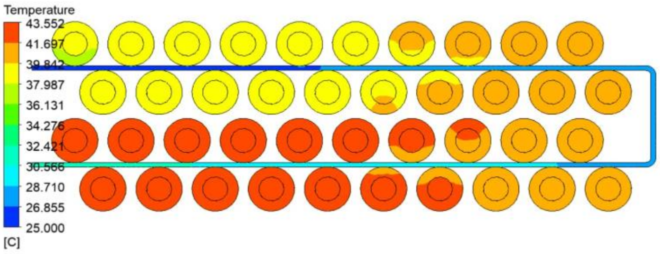

Fig.8 Temperature distribution result of U-shaped cooling channel.

6. CONCLUSION

- A comparison of the two simulation results shows that the maximum temperature difference (MTD) of the wavy cooling channel is lower than the U-shaped cooling channel, which indicates that the cooling channel of the wave can lower the temperature of the lithium battery pack as low as possible.

- By comparison we can see that the MTD of a wavy-cooling pack is also smaller than that of a U-shaped cooling pack.

- With the heat transfer information, it is easy to know that a wavy cooling channel is connected very close to the lithium battery pack, and excess heat is removed, making the MTD wavy cooling station smaller than the U-shaped cooling system.

- The above results also show that the uniformity of the temperature of the lithium battery pack with the wavy cooling channel is better. Since the design goal of this analysis is to minimize significant temperature differences, the wave cooling channel is adopted as the final cooling structure.

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