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CFD Analysis of Electric Vehicles Battery Pack: A Research Study

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Abstract

The goal of the project is to keep the battery temperature within the specified range and to improve the battery pack's performance under different temperature settings. To achieve these goals, we employ software to analyze the data and provide the necessary output. With model-based design, you can understand the dynamic behavior. For this project, a CAD model was produced with Creo Parametric. We used the STAR CCM+ Software for analysis and meshing on that. To absorb the heat from the battery cells, we placed a Silica Pad between the cooling plate and the battery pack. We have a 32-cell battery pack. Several computer simulations and mathematical modeling are used to analyze the cooling plate. We found that by varying the flow rate, there was a 10° C temperature change. 53°C was the temperature attained for this project. To do so, the flow rate is maintained at 0.9 m/s. To assess pack performance, a 3D CFD simulation can examine flow routes in addition to pressure drop, velocity, heat transfer, and local temperature. We consider the flow rate and silica absorption rate after assuming the heat dissipation rate of the cells. In our findings, the primary goal of the cooling channel study varies depending on the design in order to minimize temperature differential and pressure loss. We investigated the temperature differential between water and ethylene glycol mixture.

Keywords: EV, silica pad, cooling channel, lithium-ion phosphate battery, copper tubes, battery pack

INTRODUCTION

A useful and efficient way to increase a car's fuel economy without sacrificing performance is with hybrid electric powertrains. One essential the high voltage traction battery system, sometimes called a battery, is a component of a hybrid electric powertrain. Its duties include supplying and receiving electrical power when required by the electric machine or machines, as well as storing energy when not in use. Electrochemical cells, also called cells, are the fundamental component of batteries. They are electrically coupled to produce the required voltage range and capacity. The system resistance and subsequent heat generation caused by the current flow during battery charge and discharge raise the battery's temperature. The temperature of the battery may rise above the intended working temperature range if it is not sufficiently cooled, putting the cells at risk of damage and a shorter lifespan. In order to prevent further heat generation when the temperature rises above the intended operating range, the battery's charge and discharge power are normally decreased. The longer the full charge and discharge power is accessible, the more efficient the cooling architecture around the cells is. The usage of hybrid electric powertrains in cars is a useful way to increase fuel efficiency without sacrificing total performance. The powertrain's

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energy conversion component, the traction battery, transforms excess mechanical energy into electrical energy in order to lower mechanical output. The traction battery gets hotter due to frequent charging and discharging [1–4].

The battery's temperature will rise above its ideal working temperature if it is not sufficiently cooled. This shortens the battery's lifespan by adversely affecting its capacity to receive and distribute energy. To guarantee that the battery performs well for the duration of its design life, the ideal temperature must be reached for the battery. The majority of battery packs for hybrid electric vehicles (HEVs) are now air-cooled. The back sections of the car's cabin are frequently where the battery packs are installed. Conditioned cabin air is drawn through the battery pack and pushed into the trunk by a secondary fanblower system. Adequate air return from the rear of the cabin to the front HVAC module is hampered by the dual heat load system's architecture (the "front" A/C and the "rear" battery pack). The vehicle has two competing airflow loops, as seen from the perspective of the system [5].

A traditional centrifugal blower fan's low negative suction pressure is necessary for the primary, cabin-conditioning airflow loop to function.

Because lithium-ion batteries are lightweight, compact, and have a high density, they are the most dependable and efficient option for battery packs in electrical vehicles. In comparison to other alternative sources, it is also more affordable and readily available on the market. Its efficiency can also be easily increased by making little adjustments, as we did here when we sought to increase efficiency by adjusting the coolant's mass flow rate. As a result, the performance of our battery pack changed significantly. Battery pack CFD study is crucial, and STAR CCM+ software is used for it. In CFD, we examine and resolve many problems involving fluid flow using numerical analysis and data structures. Compared to implementing a real-world project, CFD is far less expensive. We can analyze and investigate the effects, then make the project more flexible and economical. We conducted analysis for this project using two parameters: various coolant and air flow rates.

AFFECTING FACTORS

A few things affect the thermal efficiency of the battery pack in electrical cars. A vehicle's environment changes with every step, making thermal efficiency much harder to achieve than it was before. Two measures of thermal efficiency are mass flow rate, temperature, and flow rate velocity. In contrast, the shape and size of battery cooling channels depend on the material properties. Together with battery pack design, performance is also impacted by heat absorption capacity [6–10].

Some Measurable Factors

a. *Coolant temperature:* **-** Put simply, it is the temperature of the water mixture that contains ethylene glycol that passes through a cooling channel in order to keep the temperature within certain bounds. The recommended range for the coolant temperature to meet thermal efficiency standards is 25°C to 53°C. The vehicle's coolant temperature is also influenced by the size, composition, and qualities of the cooling channels. An interior temperature that is about to exceed the summertime threshold can also be caused by the external environment's temperature.
b. *Heat input:* It is the quantity of heat that is taken in by the battery pack's walls and then transferred to a silica pad at a rate of 500 watts. The temperature is then lowered by the cooling fluid. Research papers are used to determine the absorption rate.
c. *Safety Consideration:* We eagerly anticipate enhancing the EV battery's performance while taking the user's and passenger's comfort and safety into account. Temperature increases should not exceed the specified limit as this could endanger users or passengers.

PARAMETERS

Battery Pack Configuration

The design of the battery pack has a major impact on its heating and cooling systems. We can alter the design to increase cooling effectiveness and the pace at which the silica pad absorbs heat. Because software is used for all of this work, we can select the most efficient design based on the desired outcomes, and it becomes dependable and cost-effective. Various cooling channel designs are also available to ensure an efficient flow of ethanol glycol water mixture. Meshed geometry of battery pack is shown in Figure 1.

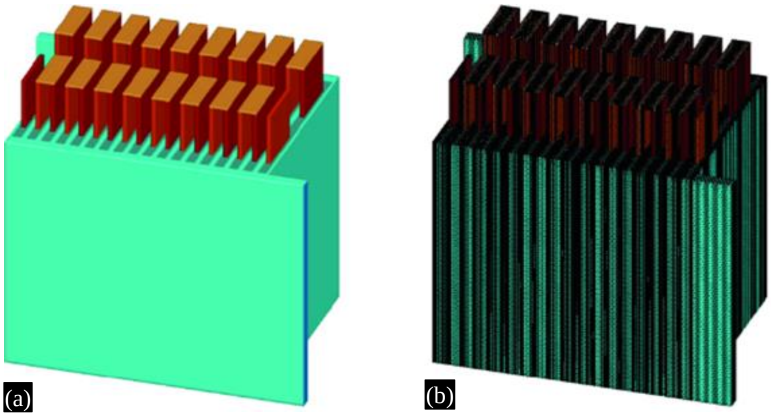

Figure 1. Meshed geometry, (a) Geometry model and (b) mesh of battery pack with fluid domain.

We took into account 3 mm copper channels in our design for the cooling system; based on our analysis, we may be able to expand the cooling channel's diameter. Although copper tubes are very expensive, their efficiency is what we currently value more than their cost-effectiveness.

Mass Flow Rates

The actual volume of fluid mixture that passes a given place at a certain pressure and temperature is the volume of the copper tube that serves as a cooling channel. The volume flowing in the duct per unit of time can be calculated by multiplying the coolant velocity by the area of a channel. computed the air flow rate at various speeds. We employed mass flow rates ranging from 0.5 to 1.0 m/s.

Geometry 1

After determining the measurements, the battery pack was developed in CREO and then imported into STAR CCM+. To verify the answer, a number of meshes containing tetrahedral elements were examined. For effective cooling, cooling tubes are installed on the battery pack's upper and bottom halves. 1,72,425 tetrahedral meshes exist. Tetrahedral -element mesh for battery pack heat generation simulation is shown in Figure 2.

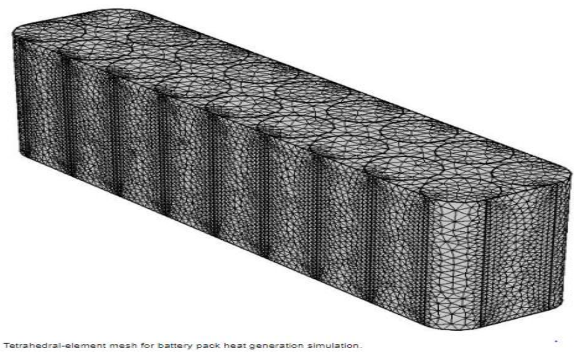

Figure 2. Tetrahedral -element mesh for battery pack heat generation simulation.

Geometry 2

The battery pack was designed in CREO and then imported into STAR CCM+ once the measurements were determined. A number of meshes with tetrahedral elements were looked at in order to confirm the answer. Cooling tubes are positioned on the top and bottom portions of the battery pack for efficient cooling.

RESULTS AND DISCUSSIONS

Case 1

With temperature and humidity control, the temperature measurement analysis was carried out in STAR CCM+. With a battery pack heat emission rate of 500 W/m2 and a starting temperature of 25°C, the final temperature was 53°C as shown in Figure 3 (I).

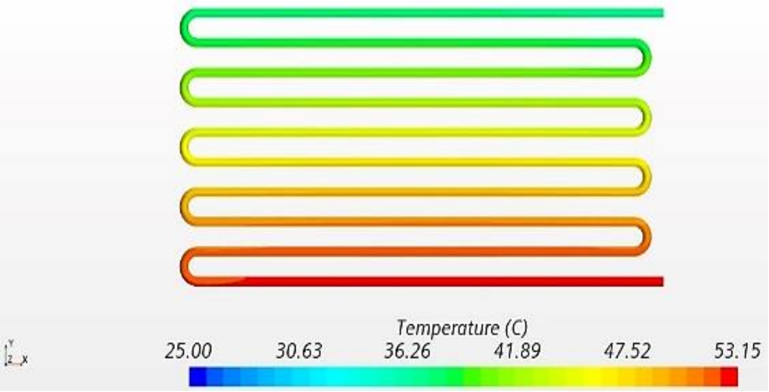

Figure 3. (I) Temperature range related to case I.

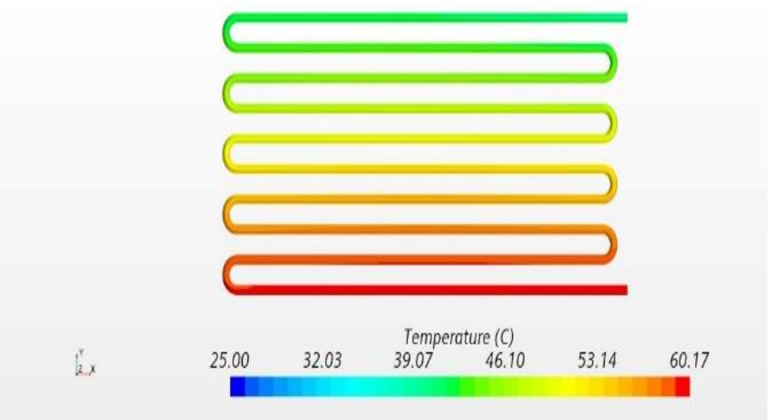

Figure 4. (II) Temperature range related to case I.

Average body temperature for 0.7m/s got 60°C as shown in Figure 4(II).

Case 2

The starting temperature was set as 25°C, and got 71°C, as shown in Figure 5.

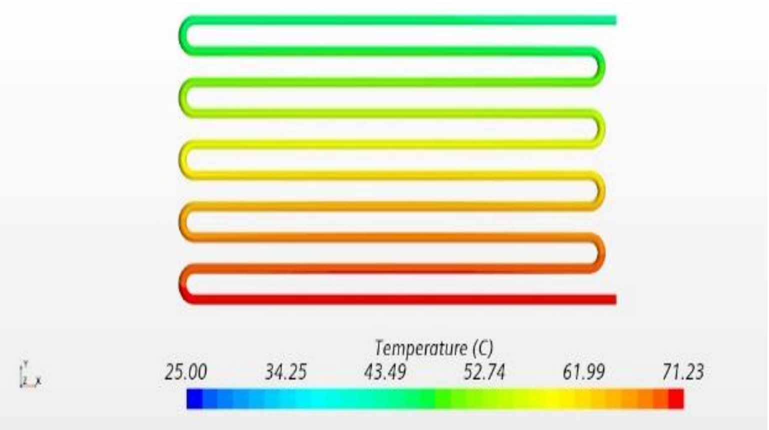

Figure 5. Temperature range related to case 2.

Results

Results have been explained in following Table 1 between mass flow rate vs temperature.

Table. 1 Mass Flow rate vs Temperature.

Mass Flow Rate	Temperature	
	ethylene glycol+water mix	water
0.5	71°C	79°C
0.7	60°C	71°C
0.9	53°C	65°C

CONCLUSION

The battery is the most common energy storage device in daily life thanks to the rapidly developing smart grid and electrical vehicles (EVs). Battery technology is expanding quickly, offering great power and energy densities. Enhancing the cooling system is similarly crucial to ensuring that the battery is a secure, dependable, and economical solution for us.

The battery pack reached a maximum temperature of 73°C at a speed of 0.5 m/s. The average temperature that we were able to sustain was 53°C.

32 Li-ion cells with high power were cooled using an indirect liquid cooling technique.

Compared to earlier study, we have achieved a temperature drop of approximately 26%. This means that the user can benefit from a longer-lasting battery pack for their car.

Acknowledgement

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