Battery Thermal Management System using Nanofluids for EVs

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Abstract – *The Battery Thermal Management System (BTMS) Plays a crucial role in effectively handling the heat generation during the charging and discharging process of battery , ensuring its safe and efficient operation. Due to higher power density BTMSs are suitable for cooling battery packages. As temperature sensitivity is a critical issue in lithium-ion batteries for EVs. The CAD model of the battery pack is generated using Design Modular geometry in Ansys. Hence, different sorts of cooling strategies is utilized in battery pack thermal management with a focus of nanofluid added. The utilization of nanofluid combined with Phase Change Materials(PCM) and Heat Pipes(HPs) are also introduced. In this project our focus is on active battery thermal management system that utilize liquid cooling technology. Hence, hybrid cooling systems based on nanofluids for BTMSs decrease temperature rise and consequently improves the temperature uniformly.*

Key Words: Battery Thermal Management System, Computational Fluid Dynamics(CFD),thermal performance of nanofluid(Water+7% Al_2O_3)

1.INTRODUCTION

A Battery Electric Vehicle (BEV) is a type of Electric Vehicles (EV) that exclusively uses chemical energy stored in rechargeable battery packs, with no secondary source of propulsion. Battery electric vehicles thus have no internal combustion engine, fuel cell, or fuel tank. Some of the broad categories of vehicles that come under this category are trucks, cars, buses, motorcycles. Lithium-ion batteries have higher energy density (100-265wh/kg) compared to other battery chemistries. They pose a risk of fire under unusual circumstances. It is crucial to operate electric vehicles in pre-defined safety limits to ensure the safety of the user as well as the vehicle. A Battery Management System (BMS), which manages the electronics of a rechargeable battery, whether a cell or a battery pack, thus becomes a crucial factor in ensuring electric vehicle safety. It safeguards both the user and the battery by ensuring that the cell operates within its safe operating parameters. In this battery pack consists of number of battery modules arranged together to produced the desired voltage, capacity or power density , they can be set up in series, parallel or both. Battery module consists of a combination of components of a battery system that includes battery cell, battery management electronics for battery cell connectors.

2.Battery Thermal Management System

A battery thermal management system keeps batteries operating safely and efficiently by regulating their temperature conditions. High battery temperatures can accelerate battery aging and pose safety risks, whereas low temperatures can lead to decreased battery capacity and weaker charging/discharging performance. A battery thermal management system controls the operating temperature of the battery by either dissipating heat when it is too hot or providing heat when it is too cold.

Battery Thermal Management System (BTMS) is essential for the following reasons:

- The thermal management system regulates the excessive heat in battery packs improving vehicles performance and efficiency.
- The primary role of BTMS is to keep battery temperature within the safe limits in order to avoid the thermal runway.
- The cooling function minimizes excessive heat in the battery pack keeping the temperature within the permitted range and limiting the adverse effect on surrounding cells.

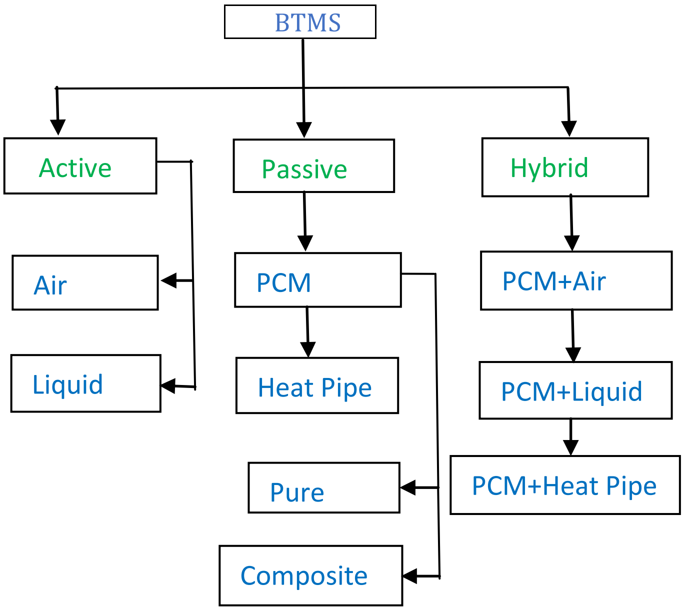

Table 1: Cooling Technologies

3.Battery Arrangement in EVs

3.1. Battery Pack: An EV battery is typically made up of thousands of rechargeable lithium-ion cells connected together to form the battery pack. Lithium-ion cells are the most popular because of their cost efficiency, offering the most optimal trade-off between energy storage capacity and price.

3.2.Battery Module: The battery electrical system refers to all the wiring, connections, fuses, and other electrical components needed to operate an EV battery. It is designed to withstand high voltages and is usually integrated with the battery management system to efficiently manage each cell.

3.3.Battery Module Array: The battery module array is the technical term that refers to the power-storing components of the battery. This includes the cells mentioned previously, which are grouped into modules, each containing a specific number of cells wired together.

3.4.Battery Management System: An EV's battery management system (BMS) is perhaps the most fundamental part of its battery. The BMS controls every aspect of the battery and ensures it performs optimally.

4.CURRENT DESIGN

4.1.Battery Cell

In this design the battery used is prismatic type lithium battery. The battery used is 120Ah NCM 622 manufactured by Samsung whose composition is Lithium Manganese Cobalt Oxide (Nickel: Cobalt: Manganese=6:2:2 ratio). In each battery module for the present design there are 12NCM 6222 battery cells and the battery pack has 8 battery modules each. Dimensions of the battery modules are 40.95cm*30.11cm*15.24cm.

Product: Lithium Nickel Cobalt Manganese Oxide NCM 622
Molecular Formula: $LiCoMaO_2$
NCM ratio=6:2:2
Charge temperature range: 0° C to +65° C
Discharge temperature range: -20° C to +55° C
Storage: -20° C to +65° C
Melting point: 290° C
Boiling point: 1342° C
Specific energy: 150-220 Wh/Kg
Rated Voltage: 3.7 V
Nominal Capacity: 120 Ah

Fig1:Battery Cell

4.2.Battery Pack Arrangement

The figure deals with the arrangement of battreyu modules in the battery pack, and closed circuit flow of nanofluid (Water+7%Al_2O_3).The outlet hot fluid from the battery module 8 will flow will flow through chiller to obtain initial temperature. The chiller is connected to AC circuit where it uses refrigerant to cool down the nano-fluid.

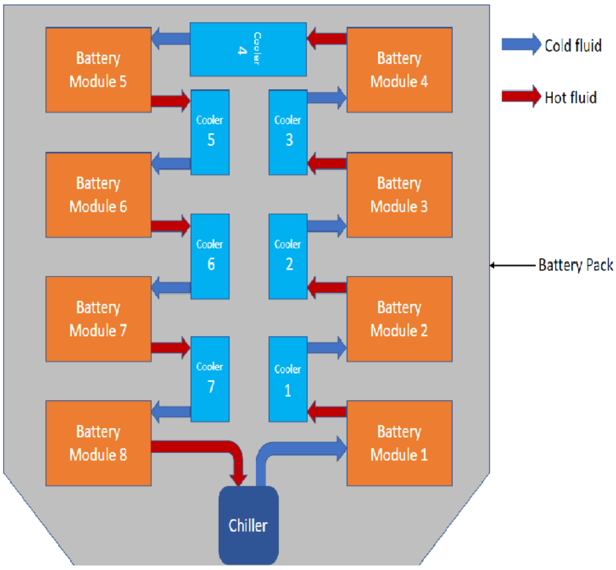

Fig2: Arrangement of Battery Packs and nanofluid

4.3. Thermal Network Diagram

The figure below shows the thermal network diagram of the current design. This figure shows the flow of nano-fluid throughout the network. In chiller there are two loops one connecting to the battery and other connected to a air-conditioner. This air-conditioner fluid is used to bring back the nano-fluid temperature to its initial temperature using air-conditioning of a vehicle.

Heat is gained by the fluid when it passes through the battery module and heat is rejected(cooled) by the fluid when it passes through the cooler.

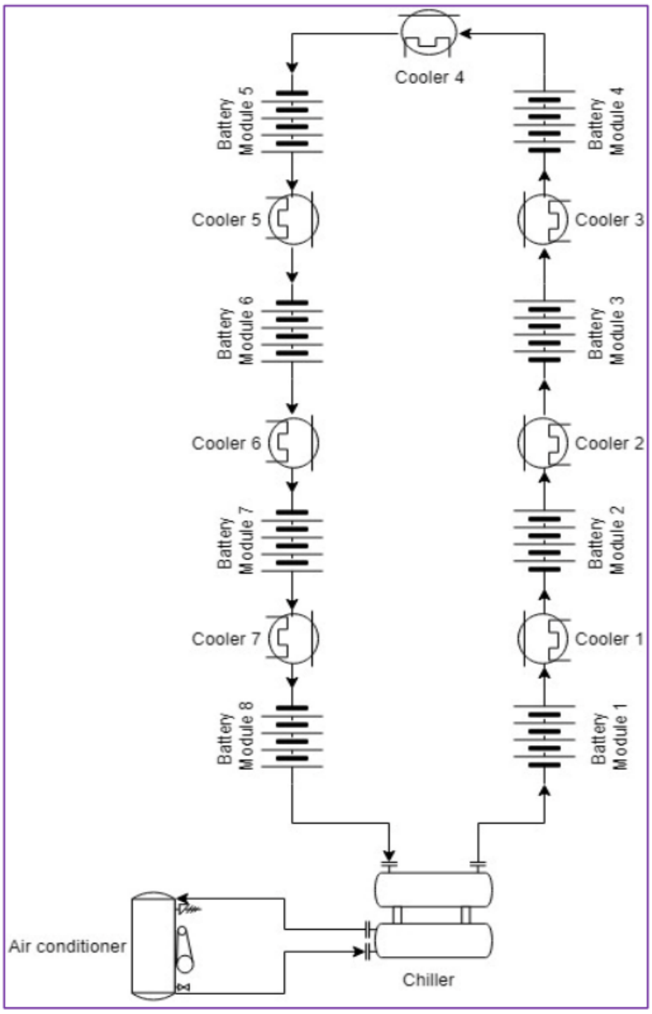

Fig3: Thermal Network Design

4.4.Prototype Design

The figure shows one-layer arrangement of battery modules in the battery pack. The battery pack designed for our vehicle has three layers of this battery module arrangement. In our project we are looking for only one layer as the result can be replicated to other layers. The layers can be stacked up vertically.

The cooling is provided to battery module surface. The eight large compartments are the cooling jackets whose below surface are in contact with eight battery modules. The small compartments below surface is in contact with thermos-electric coolers.

The nano-fluid flows form the cooling jackets and absorbs heat from the battery module surface resulting in heating of nano-fluid. After heating the nano-fluid flows through the jacket where the below surface is in contact with the cooler resulting in cooling of a nano-fluid.

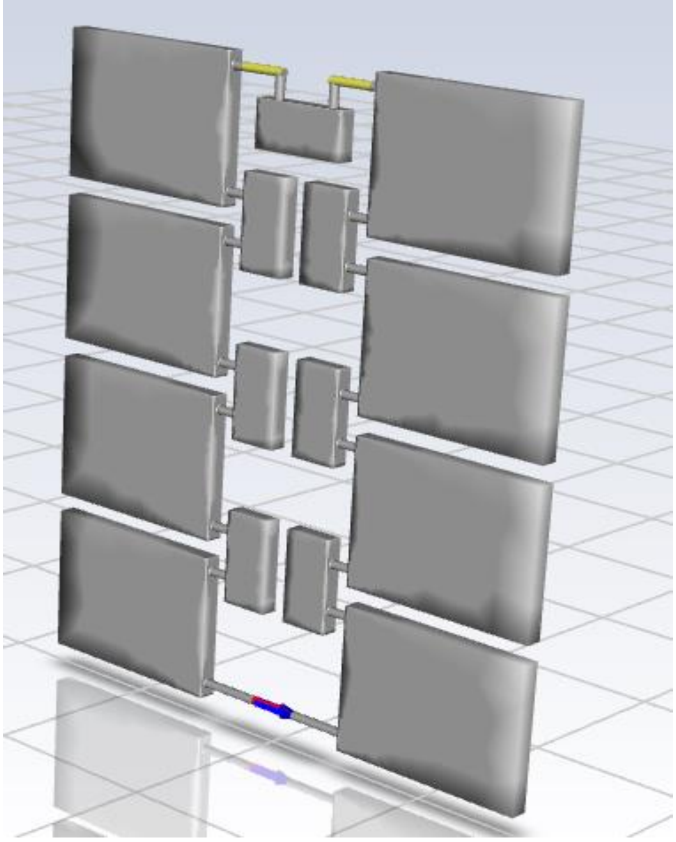

Fig4: Prototype Design

5.Initial Result Analysis

Inputs for the test:

- Battery Surface Temperature: 30degree
- Inlet fluid velocity: 1m/s
- Inlet nanofluid temperature: 18 degree

Case 1: Comparison between heating and cooling of nanofluid when cooler is on and off at temperature of 18 degree.

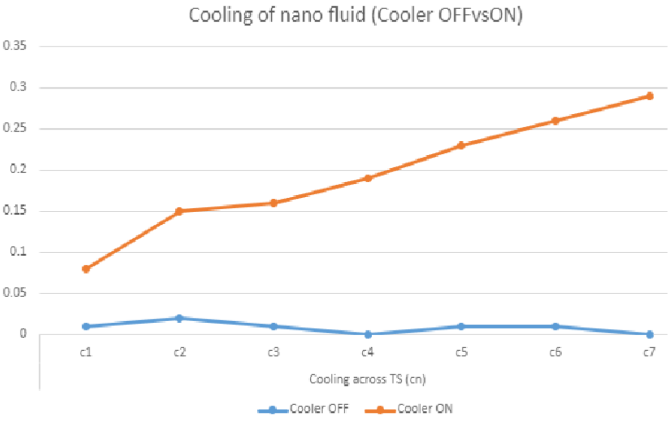

Fig5: Cooling of Nanofluid(Cooler ONvsOFF)

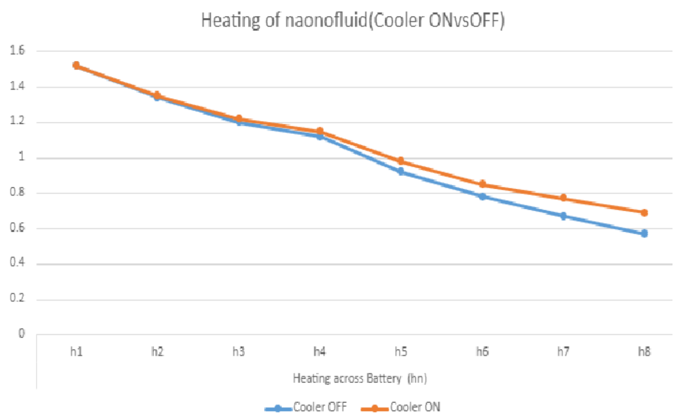

Fig 6:Heating of Nanofluid(Cooler ONvsOFF)

From above Fig 5 it is evident that when cooler is on ,the cooling effect can be seen on nanofluid. From Fig 6 we can see that heating of nanofluid is more when cooler is ON. This is due to the temperature difference created by cooler. Hence, we can conclude that cooler in nanofluid tends to absorb more heat from the battery as compared to when cooler is OFF.

According to the given conditions:

Thermo-Physical Properties of Nano-fluid:

Fluid-Water+7%Al$_2$O$_3$

Density-1205.81(kg/m^3)

Specific Heat-3437.94(J/KgK)

Thermal Conductivity-0.7264(W/mK)

Viscosity-0.001175(PaS)

Cooler Temperature for highest cooling graph are;

C1=14 ,C2=18,C3=2,C4=10,C5=10,C6=14,C7=18

Cooling for TS(cn) for the highest cooling graph obtained from Ansys Calculations are:

c1=0.343,c2=0.2,c3=1.206,c4=0.759,c5=0.788,c6=0.517,

c7=0.369

Heating across battery(hn) for highest cooling graph obtained from Ansys Calculations are:

h1=1.9,h2=1.771,h3=1.527,h4=1.931,h5=1.215.h6=1.193 ,h7=1.023,h8=0.828

As a result considering above graphs, comparing all cooler values , c3 is having maximum cooler temperature whereas for batteries h3 is having maximum heating performance.

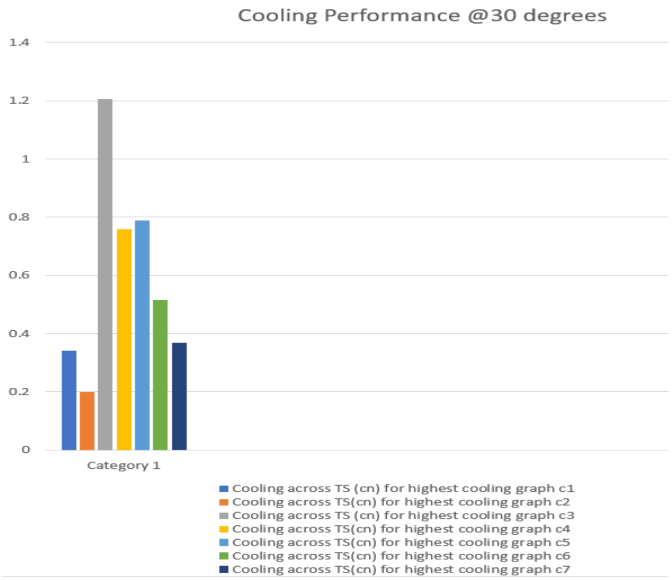

Fig 7: Cooling Performance @30degree

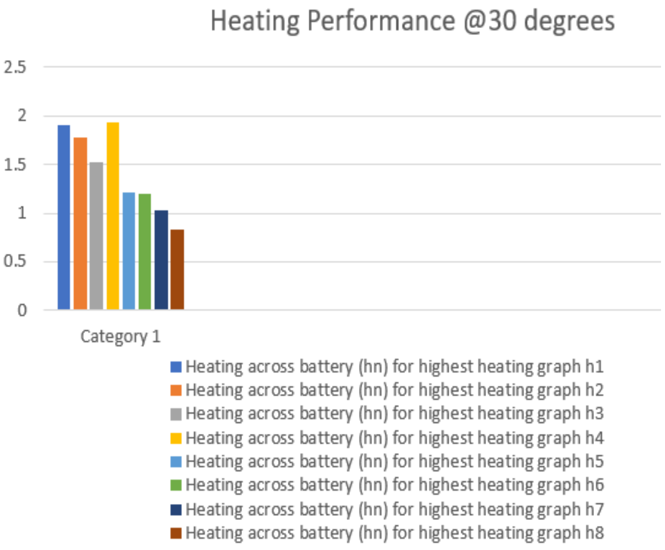

Fig 8: Heating Performance @30 degree

6.ADVANTAGES

- It provides continuous and stable cooling performance.
- The nanofluids helps to maintain the battery temperature thereby preventing burnouts of batteries.
- It improves the battery performance.
- It ensures faster charge rates, improved driving performance, and most importantly provides battery safety.

7.CONCLUSION

In this research, developing a nanofluid that will enhance battery and improve performance is in the interest of research and the automotive industry. Hence, nanofluids used during the operation of battery can increase the performance of vehicle. Therefore, this research studied the improvement in an air-cooled thermal management system by utilizing two distinct nanofluids while looking at the transient operation. Our results revealed that the utilization of nanofluids results in higher vortex development and enhances heat transfer capabilities of the fluid. Through a comprehensive analysis, we found that Al_2O_3 exhibited superior heat transfer performance. Even during a high-performance, mode the temperature of the batteries were effectively maintained at a safe range through the utilization of nanofluid for liquid cooling.

During the transient analysis it is observed that the utilization of 7% Al_2O_3 resulted in reduction of temperature of batteries. This demonstrates the effective cooling of the batteries using nanofluids can help in managing and controlling the temperature even during high demand operations. Increasing the velocity of the fluid led to enhanced turbulence, which in turn improved the heat transfer performance. However, this improvement came at the expense of a higher pressure drop. Using nanofluids tends to improve thermal conductivity and enhances stability by heat transfer. In high performance mode the temperature of the batteries were effectively maintained within a safe range through the utilization of liquid cooling.

8.REFERENCES

[1] International Energy Agency (IEA). World Energy Outlook.Availableonline: **https://www.iea.org/reports/world-energy-outlook-2010** (accessed on 5 May 2022).

[2] Tran, M.; Banister, D.; Bishop, J.D.; McCulloch, M.D. Realizing the electric-vehicle revolution. *Nat. Clim. Change* **2012**, *2*, 328–333.

[3] K. Shimitzu, N. Shirai, and M. Nihei, “On-board battery management system with SOC indicator,” in Proc. Int. Electric Vehicle Symp., vol. 2, 1996, pp. 99–104.

[4] He, S.; Xiong, B.; Lei, H.; Dong, K.; Khan, S.A.; Zhao, J. Optimization of low-temperature preheating strategy for Li-ion batteries with supercooling phase change materials using response surface method. *Int. Commun. Heat Mass Transf.* **2023**, *142*, 106635.

[5]Pattipati, B.; Pattipati, K.; Christopherson, J.P.; Namburu, S.M.; Prokhorov, D.V.; Qiao, L. Automotive Battery Management System. In Proceedings of IEEE AUTOTESTCON, Salt Lake City, UT, USA, 8–11 September 2008; pp. 581–586

[6] Keyser, M.; Pesaran, A.; Oweis, S.; Chagnon, G.; Ashtiani, C. Thermal Evaluation and Performance of High-Power Lithium-Ion Cells; National Renewable Energy Lab. (NREL): Golden, CO, USA, 2000.

[7] Moghadasi, R.; Rostami, A.; Hemmati-Sarapardeh, A. Application of nanofluids for treating fines migration during hydraulic fracturing: Experimental study and mechanistic understanding. *Adv. Geo-Energy Res.* **2019**, *3*, 198–206.

[8] Rahmati, A.R.; Akbari, O.A.; Marzban, A.; Toghraie, D.;Karimi,R.; Pourfattah, F. Simultaneous investigations the effects of non-Newtonian nanofluid flow in different volume fractions of solid nanoparticles with slip and no-slip boundary conditions. *Therm. Sci. Eng. Prog.* **2018**, *5*, 263–277.

[9] Yu, X.; Lu, Z.; Zhang, L.; Wei, L.; Cui, X.; Jin, L. Experimental study on transient thermal characteristics of stagger-arranged lithium-ion battery pack with air cooling strategy. *Int. J. Heat Mass Transf.* **2019**, *143*, 118576.

[10] .D. Bell, “A battery management system,” Master’s thesis, School Eng., Univ. Queensland, St. Lucia, Australia, 2000.

[11] Pesaran, A.A. Battery thermal management in EV and HEVs: Issues and solutions. *Battery Man* **2001**, *43*, 34–49.