Design, Optimization, and Analysis of Electric vehicle Battery Pack

Rahul Patil[1], Parth Punekar[2], Rohan Patil[3]

[1-2]Department of Mechanical Engineering, Dr.D.Y.Patil Institute of Engineering, Management & Research, Akurdi, Pune, Maharashtra, India
[3]Department of Mechanical Engineering, K.K. Wagh Institute of Engineering Education & Research, Nashik, Maharashtra, India

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Abstract - *Lithium-ion batteries are used for their high energy efficiency and are frequently used by electric car manufacturers typically employ them (EVs). However, abrupt temperature changes cause these batteries to lose efficiency quickly. Liquid cooling, a majorly used thermal management approach that increases battery pack service life, is one way to limit temperature rises (whether ambient or created by the battery itself). Because of their low rate of self-discharge, high energy density, and long life cycle, lithium-ion batteries have a wide range of applications. They have a high energy density in relation to their weight. Choosing the right cooling mechanism for a lithium-ion battery pack for electric vehicles and developing an appropriate cooling control plan to maintain the heat contained within a safe range of 15 to 40 degrees Celsius is critical to boosting safety, extending the pack durability, and lowering cost. The design and analysis of the battery pack are presented in this paper. The temperature difference between the battery cell and the cooling fluid is depicted in this paper.*

Key Words: **Electric vehicle, Lithium-ion batteries, Aluminium tubes.**

1. INTRODUCTION

The industry for electric drive vehicles (EDVs) is growing, and it has much more potential if batteries have more power, can travel longer ranges, and are less costly. The battery thermal management technology in electric vehicles (EVs) and hybrid electric vehicles (HEVs) should keep temperatures within a proper range of 15 0C to 40 0C to keep lithium-ion (Li-ion) battery packs functioning safely and extending their life. The battery pack generates a large amount of heat during vehicle operation, which must be dissipated. The removal of heat generated and having a constant temperature in EDVs has become a challenge due to the higher demand for gravimetric and volume energy. A variety of cooling techniques are proposed and tested.

A battery in an electric vehicle is usually cooled in one of the following ways:

1. Air cooled

2. Liquid-cooled

3. Cooling by fins

4. PCM (phase change material) cooling

Despite the fact that each cooling method has pros and cons, studies show that liquid cooling is a viable option for Li-ion battery packs in EVs due to its size, weight, and power requirements. Even though immediate liquid cooling requires drenching the battery cells in the fluid, a low (or no) conductivity cooling liquid is essential. For indirect liquid cooling to work, the battery cells do not need to be in immediate contact with the cooling medium.

Alternatively, the liquid coolant can be circulated through the system's metal pipes, which necessitates the use of anticorrosion protection on the metal. Liquid cooling, an efficient thermal management strategy that extends battery pack service life, is one way to control temperature rises (whether environmental or generated by the battery itself). Engineers can use Multiphysics simulation to study liquid cooling in batteries and optimize thermal management.

1.1Problem Statement

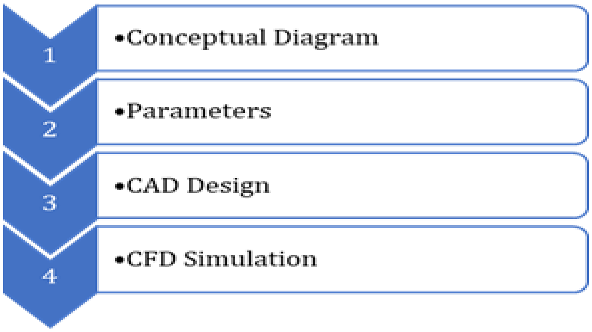
Heat makes electric vehicle batteries work harder, and it is a major battery killer. Batteries will stop working, swell, bubble, cause sparks and flames, harm your device, or blow up if they are exposed to too much heat. Extreme heat can shorten the life of a battery by causing corrosion.

The components inside lithium-ion batteries begin to degrade when they are overcharged or overheated, releasing oxygen, carbon dioxide, and other gases in the process. As pressure builds, the heated battery expands from a rectangle to a pillow shape. For increasing safety, extending pack service life, and lowering costs, selecting the right cooling method for a lithium-ion (Li-ion) battery pack for electric drive vehicles (EDVs) and developing an optimal cooling control strategy to keep the temperature between 15 and 40 degrees Celsius is critical. Prices, complexity, weight, cooling effects, temperature uniformity, and parasitic power are all factors to consider when choosing a cooling technology and developing strategies.

1.2 Objective

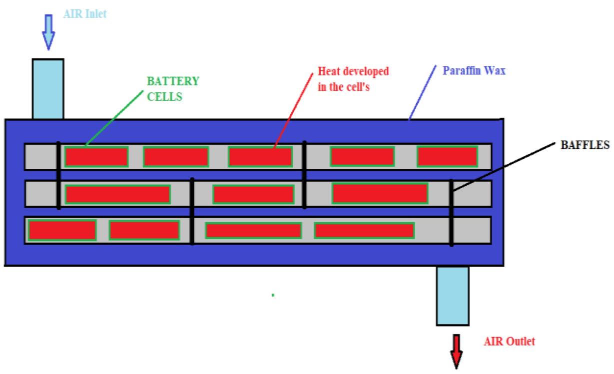
- To efficiently lower the battery's temperature.
- Lower the cost of an electric vehicle's cooling system.
- Cooling systems must be working within a safe range of 15 to 40 degrees Celsius for the battery pack.
- Using CATIA v5 or Space-clime software to create a 3D conceptual modal.
- Using ANSYS fluent R1 2020 soft to solve the FEM solution to the intended modal.
- Changing the working medium
- Record the temperature variation for different Work in the medium.

2. Methodology



2.1 Conceptual Design

We got the idea for the design and development of the battery pack from research papers, and we can increase the cooling efficiency by combining paraffin wax with water. So I wrapped paraffin wax around the aluminum plate, and there were battery cells inside the aluminum plate. We will investigate heat transfer efficiency around the battery cells, aluminum tubes, and chamber using the ANSYS fluent system and the transient method.



2.2 Parameters and Specification

For the purposes of this project, the battery and shell parameters are assumed.

Solid shell for exchanging heat

Length = 60 cm
Diameter = 27.5 cm
Shell thickness = 1.5 cm

Shell inlet and outlet

Outer Diameter= 6cm
Inner Diameter= 3.5cm

Aluminum tube

Thickness = 0.1 cm
Length = 30 cm
Outer dia= 6 cm
Inner dia = 5.8 cm

Battery Cells

Diameter= 5.8cm
Length = 12cm

Baffle Plate

Thickness =0.5cm
Outer Diameter= 8cm
Inner Diameter= 6cm

PCM Solid coating

Thickness = 0.2 cm
Length = overall aluminum tube

The velocity of the water entering the tube

Velocity = pi*d*n/60
N = rpm of the water motor is considered as = 1400
D =3.5 cm
V =2.56 approx
Temperature = normal room temperature at 24^0 Celsius

Battery model parameter

Single battery condition with series and parallel setup
Volts = capacity/current rate
The capacity of the battery to produce amp/hour = 14.2
Current rate = 0.3
Approx. 4.26 analytical

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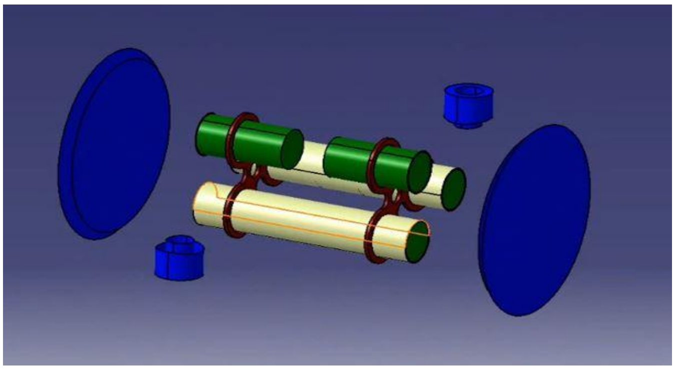
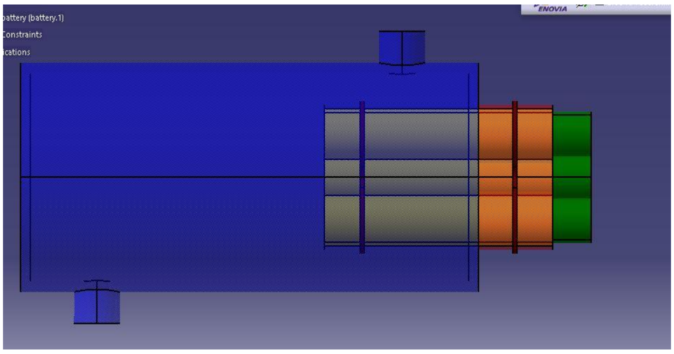
2.3 CAD Design

In this system, we are developing a 3D modal using CATIA v5 R20

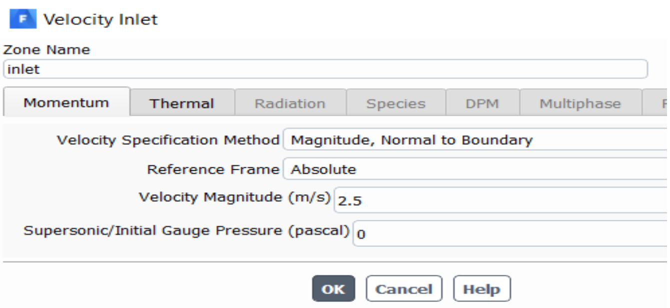




2.4 Ansys

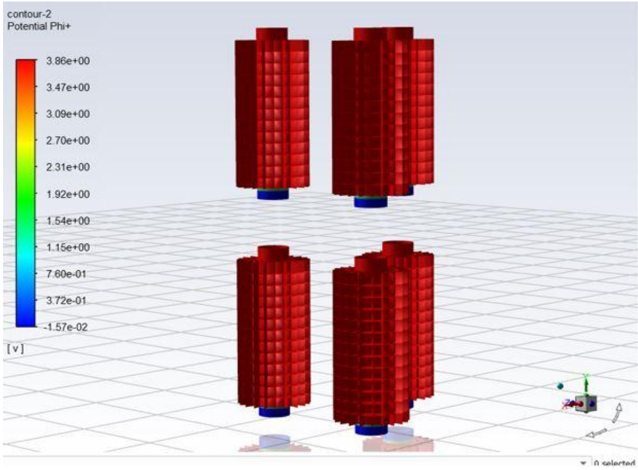
Boundary Conditions for Cooling

The boundary condition for all cooling mediums is the same. We consider laminar flow with velocity 2.5m/s and temperature 23.999994 ^{0}c.



2.5 Ansys Results

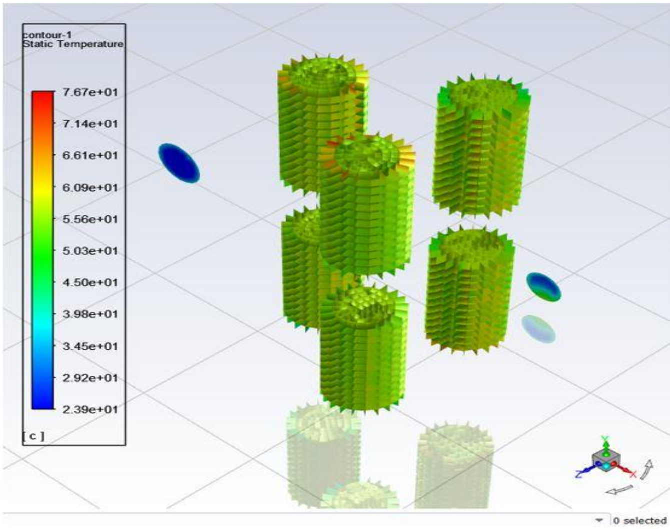
Potential volt generated for 1 hour. Potential Phi of the battery max 3.8 volts from positive to 0 at the negative terminal and without using any cooling medium 64.999994 ^{0}C got




```
Calculation complete.

              Area-Weighted Average
                      Potential Phi+                 (v)
-------------------------------- --------------------
            interior-solid_cell            3.8620729
         wall-tabnegative_zone                     0
         wall-tabpositive_zone            3.8620729
                ---------------- --------------------
                             Net            3.8377325

              Area-Weighted Average
                           Density              (kg/m3)
-------------------------------- --------------------
            interior-solid_cell                    0
         wall-tabnegative_zone                     0
         wall-tabpositive_zone                     0
                ---------------- --------------------
                             Net                    0

              Area-Weighted Average
                 Static Temperature                  (c)
-------------------------------- --------------------
            interior-solid_cell            64.999994
         wall-tabnegative_zone             64.999946
         wall-tabpositive_zone             64.999916
                ---------------- --------------------
                             Net            64.999993
```

Iteration 1 Cooling with Water at a given boundary condition

The temperature got 57.379999 ^{0}C in the battery cells.



```
Calculation complete.
            Area-Weighted Average
               Static Temperature                       (c)
-------------------------------- --------------------
                            inlet            23.999994

            Area-Weighted Average
               Static Temperature                       (c)
-------------------------------- --------------------
                           outlet            36.432541

            Area-Weighted Average
               Static Temperature                       (c)
-------------------------------- --------------------
               interior-solid_cell            57.379999

            Area-Weighted Average
               Static Temperature                       (c)
-------------------------------- --------------------
        interior-solid_cell-shadow            58.655378

            Area-Weighted Average
                   Potential Phi+                       (v)
-------------------------------- --------------------
               interior-solid_cell             3.870492
             wall-tabnegative_zone                    0
             wall-tabpositive_zone             3.870492
                 ---------------- --------------------
                              Net             3.8582534
```

Iteration 2 -Air Results

The temperature got 57.338504 ^{0}C in the battery cells.

```
Calculation complete.
Writing "| gzip -2cf > FFF-1-1-00010.dat.gz"...
Writing temporary file C:\Users\GANESH~1\AppData\Local\Temp\flntgz-44924 ...
Done.


        Area-Weighted Average
          Static Temperature                (c)
-------------------------------- --------------------
             wall-solid_shell         57.338504
```

```
            Area-Weighted Average
                  Static Pressure                 (pascal)
-------------------------------- --------------------
                            inlet             6.5252861
                           outlet       -0.00048038088
                 ---------------- --------------------
                              Net             3.262403
```

```
            Area-Weighted Average
               Velocity Magnitude                     (m/s)
-------------------------------- --------------------
                            inlet                  2.5
                           outlet            2.4742687
                 ---------------- --------------------
                              Net            2.4871343
```

Iteration 3 -Ethylene glycol Results

The temperature got 57.379999 ^{0}C in the cells.

```
-------------------------------- --------------------
              interior-solid_cell            57.379999
                 wall-solid_shell            49.952687
            wall-tabnegative_zone            57.257271
                 ---------------- --------------------
                              Net            53.906648

            Area-Weighted Average
               Static Temperature                   (c)
-------------------------------- --------------------
              interior-solid_cell            57.379999
```

```
            Area-Weighted Average
               Velocity Magnitude                 (m/s)
-------------------------------- --------------------
                            inlet                  2.5
                           outlet            2.5136373
                 ---------------- --------------------
                              Net            2.5068187
-
            Area-Weighted Average
                  Static Pressure              (pascal)
-------------------------------- --------------------
                            inlet            6738.8717
                           outlet                    0
                 ---------------- --------------------
                              Net             3369.436
```

Iteration 4- Water with PCM of 0.2 cm thickness

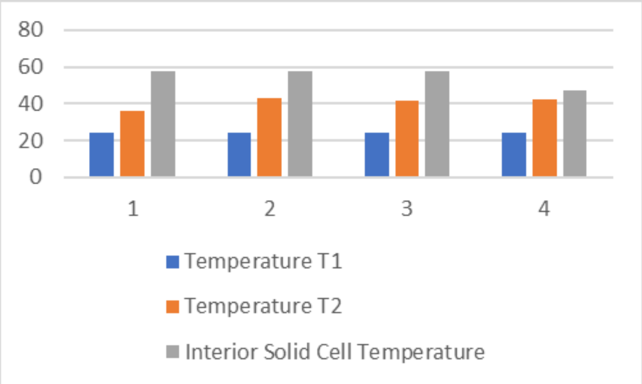
The temperature at the battery cell is 47.302372 ^{0}C.

```
>
            Area-Weighted Average
               Static Temperature                       (c)
-------------------------------- --------------------
                            inlet            23.999994
inneralu_pipe-contact_region-contact_region_15-
contact_region_2-contact_region_3-contact_region_6-
contact_region_15-contact_region_16-contact_region_17-
contact_region_2-contact_region_20-contact_region_43-
contact_region_19-contact_region_20-contact_r
37.71753
              interior-solid_cell            48.296991
                           outlet            42.211524
            wall-tabnegative_zone            48.290702
            wall-tabpositive_zone            48.290437
                 ---------------- --------------------
                              Net            47.302372
```

3. CONCLUSIONS

Materials are expensive, and obtaining components required for specific rages is difficult. With these research findings, other direct cooling methods have entered the market. However, this was our attempt to put the model into action. A water cooling system with PCM coating over aluminum is effective. We've created tables and graphs to compare the temperature differences between various cooling mediums.

Sr.No.	Type of Working Medium	Outlet Temperature T2 ^{0}C	Interior-Solid Cell ^{0}C
1	Water	36.432541	57.379999
2	Air	42.884944	57.338504
3	Glycol	41.444251	57.379999
4	PCM	42.211524	47.302372



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