

ANALYSIS ON BTMS USING ALUMINIUM BAR AND THERMOELECTRIC GENERATOR

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering
by

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**DEPARTMENT OF MECHANICAL ENGINEERING SCHOOL
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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

**Accredited with grade "A" by NAAC | 12B Status by UGC | Approved by
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DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **R.Sunil (391500125)** and **L.Shaffrin (39150119)** who carried out the project entitled
"ANALYSIS ON BTMS USING ALUMINIUM BAR AND THERMOELECTRIC GENERATOR" under our supervision from November 2022 to April 2023.

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DECLARATION

I, **R.Sunil** and **L. Shaffrin** hereby declare that the Project Report entitled **ANALYSIS ON BTMS USING ALLUMINIUM BAR AND THERMOELETRIC GENRATOR** done byme under the guidance of **Dr. M. ANISH, M.E., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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1.



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SIGNATURES OF THE CANDIDATES

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I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways in the successful completion of the project.

ABSTRACT

The transition to electric mobility, owing to their proposition as a solution to the environmental qualms of rising levels of pollution due to the utilization of conventional sources of energy (fossil fuels), has directed the attention of researchers to the main energy storage system of the electric vehicles that is batteries. With Lithium-ion chemistry proving to be an efficient battery technology in terms of energy density, specific power, safety, durability, and reduced emissions; the requirements for their optimum operation include a temperature range of 15°C - 35°C. The objective of this work is to analyze the different BTMSs for different arrangements of cells in a battery module using CFD and utilize the results of the analysis to propose the optimum, costeffective, and low maintenance BTMS for enhanced performance of the battery module. The CFD analysis is performed the assessment of the airflow using ANSYS Fluent. The analysis of the air flow through the battery module can give a better insight on temperature reduction in the battery pack. In recent times , people mostly using electric vehicle , So the battery thermal management system on the electric vehicles are major technique used by present times. But vehicles are exploding because of over efficiency of the battery temperature . But can able control the battery efficiency using Thermoelectric Generator and using Aluminium bar the environmental qualms of rising levels of pollution due to the utilization of conventional sources energy of the fossil fuels has directed the attention of researchers to main energy storage system of the electric vehicles to the batteries.

TABLE OF CONTENT

CHAPTER NO.	PARTICULARS	PAGE NO.
	ABSTRACT	I
	LIST OF TABLES	III
	LIST OF FIGURES	IV
1	INTRODUCTION	1
	1.1 INTRODUCTION	1
	1.2 MOTIVATION OF THE PROJECT	2
	1.3 BATTERY THERMAL MANAGEMENT SYSTEM	3
	1.4 OBJECTIVE OF THE PROJECT	4
2	LITERATURE SURVEY	5
3	METHODOLOGY	9
	3.1 TYPES OF COOLING	
	3.2 METHODOLOGY	10
	3.3 PROCESS FLOW CHART	12
	3.4 PASSIVE COOLING TECHNIQUE	13
	3.5 BATTERY CONFIGURATION	14
4	EXPERIMENTAL PROCEDURE	15
	4.1 CAD MODEL	15
	4.2 TEMPERATURE ANALYSIS	15
	4.2.1 WHILE CHARGING	15
	4.2.2 WHILE DISCHARGING	16
	4.3 ANALYSIS PROCEDURE	17
	4.3.1 MESHING	19
	4.3.2 SETUP	20
	4.3.3 RESULT	21

	4.4 TERMOELETRIC GENERATOR	22
	4.5 COOLING METHOD	24
5	CALCULATION	25
	5.1 CHARGING TIME	25
	5.2 DISCHARGING TIME	27
	5.3 HEAT GENERATED	27
	5.4 MASS FLOW RATE	28
6	CONCLUSION SAND REFERENCES	
	6.1 CONCLUSION	29
	6.2 REFERENCES	30

LIST OF TABLES

TABLE NO	TITTLE	PAGE NO
3.2	PROPERTIES OF DENSITY IN BATTERY	12
4.3	ANALYSIS ON ANSYS	18

LIST OF FIGURES

FIGURE NO	TITTLE	PAGE NO
1.3	BATTERY MANAGEMNT SYSTEM	4
3.1	FLOW CHART OF COOLING METHOD	9
3.2	EXHAUST	10
3.3	FLOWCHART OVERVIEW OF BTMS	12
3.4	PASSIVE COOLING METHOD	13
3.5	RECHARGEABLE BATTERY	14
4.1	WORKING MODEL	15
4.2.1	POWER SOURCE	16
4.2.2	CHARGING AND DISCHARGING	17
4.3	FRONT VIEW OF THE MODEL	18
4.3.1	TOP VIEW OF THE MODEL	19
4.3.2	SETUP BOX OF THE ANSYS	20
4.3.3	SIDE VIEW OF THE MODEL	21
4.4	TERMOELETRIC GENERATOR	23
5.1	CHARGING TIME GRAPH	25

LIST OF THE ABBREVIATIONS

EV	ELECTRIC VEHICLE
BTMS	BATTERY THERMAL MANAGEMENT SYSTEM
CFD	COMPUTATIONAL FLUID DYNAMICS
ANSYS	ANALYSIS OF SYSTEM
FCEV	FUEL CELL ELETRIC VEHICLE
PCM	PULSE CODE MODULATION
CFX	COMPUTATIONAL FLUID DYNAMICS PROGRAM
TEG	THERMOELETRIC GENEATOR
CAD	COMPUTER AIDED DESIGN
NREL	NATIONAL RENEWABLE ENERGY LAB

CHAPTER 1

1.1 INTRODUCTION

Rising pollution levels, climate change and global warming are the pressing issues which have made the requirement of alternate energy source utilization imperative. The transition to electric vehicles is the current focus as far as the automotive industry's contribution is concerned. Batteries are the most feasible amongst the various alternative energy storage systems, owing to their efficient peak and average power delivery rates . Out of the several existing battery technologies, the Lithiumion battery technology is primarily used because of its high specific power, energy density, longer life cycle, reduced weight, and absence of memory effect. However, the thermal sensitivity of these batteries, significantly impacts their overall performance and durability. The Li-ion packs are also known to generate significant amount of heat during these scenarios thereby leading to potential thermal runaway that could propagate a cell to destruct violently. Therefore, the design and implementation of a successful thermal management system is extremely important. .The primary aim of a thermal management system is to effectively dissipate the heat in a battery pack by ensuring that the batteries are operating in the desired temperature range (specific to the application) while also working towards reducing non uniformities in temperature distributions inside of the pack.

The importance of a cooling system , While advancements have been made in electric vehicle batteries that allow them to deliver more power and require less frequent charges, one of the biggest challenges that remain for battery safety is the ability to design an effective cooling system. In electric cars, discharging the battery generates heat; the more rapidly you discharge a battery, the more heat it generates. Batteries are only manufactured to work between certain temperature extremes, they will stop working if there is no cooling system to keep it in a working range. Cooling systems need to be able to keep the battery pack in the temperature

range of about 2040 degrees Celsius. There are a few options to cool an electric car battery—with phase change material, fins, air, or a liquid coolant.

In recent times , people mostly using electric vehicle , So the battery thermal management system on the electric vehicles are major technique used by present times. But vehicles are exploding because of over efficiency of the battery temperature . But can able control the battery efficiency using Thermoelectric Generator and using Aluminium bar the environmental qualms of rising levels of pollution due to the utilization of conventional sources energy of the fossil fuels has directed the attention of researchers to main energy storage system of the electric vehicles to the batteries.

1.2 MOTIVATION FOR THE PROJECT

The operating conditions are limited to a narrow temperature range of 15°C and 35°C for optimum operation of Lithium-ion battery systems. Our idea is inspired from the existing types of cooling systems for battery thermal management system in electric vehicles Out of the existing technologies , we chose liquid cooling technology for our project .

Now a days EV are emerging as future mobility. As it is concern , the range , efficiency and the charging method have its own disadvantage. While advancements have been made in electric vehicle batteries that allow them to deliver more power and require less frequent charges, one of the biggest challenges that remain for battery safety is the ability to design an effective cooling system. While charging and discharging the battery will get heated to certain temperature , we have to main the battery temperature within 20 to 45 degree celsius , else the range and efficiency will get affected. For that the Battery Thermal Management system plays a major role.

1.3 BATTERY THERMAL MANAGEMENT

Thermal management of battery systems in electric vehicles is critical for maintaining energy storage capacity, driving range, cell longevity and system safety. The Battery Thermal Management System (BTMS) is the device responsible for managing/dissipating the heat generated during the electrochemical processes occurring in cells, allowing the battery to operate safely and efficiently. The BTMS's (Battery Thermal Management System) objective is to prevent accelerated battery deterioration by managing the heat generated by its components so that it operates continuously under optimum temperature conditions.

Although existing commercially available cells can operate safely between -40 and 60 °C, the operating range preferred by manufacturers to maximize their performance is indeed between 15 and 35 °C. In this sense, it is also recommended that within the battery-pack there should not be a difference of more than 5 °C between the cells.

It should be noted that exposing the battery to extreme conditions can have fatal consequences. For example, in Fig:1.3 its operation at very high temperatures (> 80 °C) can cause the well-known thermal runaway, resulting in fire and, in the worst scenario, the explosion of the battery with the consequent personal safety implications.

The BTMS is the battery-pack component responsible for ensuring that the cells operate under the optimum temperature conditions specified by the manufacturer.



Fig 1.3: Battery Management system.

1.4 OBJECTIVES OF THE PROJECT

- ❖ Cooling the battery before it overheats.
- ❖ Increasing the range of the battery by maintaining it at optimum temperature.
- ❖ Accessing the vents for cooling according to the driver's comfort .
- ❖ Increases the SOH (State of Health) of Battery .

CHAPTER 2

LITREATURE SURVEY

Kim (2019). The mobility future now belongs to the Electric Vehicles. Many nations and their government policies are supporting this mission. Along with the rapid growth of EVs in last few years, demand for quick charging, high efficiency and longer battery life as increased. To cater this, manufacturers have started generating high power batteries with quick charging. With faster charging-discharging cycles, there comes a challenge to maintain the efficiency with faster heat dissipation. One such way is immersion cooling, which has recently started to be practiced in EVs .

H.P.J. De Wilde, P. Kroon (2020). Specific attention is paid to the effects of temperature and thermal management on capacity/power fade, thermal runaway, and pack electrical imbalance and to the performance of lithium-ion cells at cold temperatures. Furthermore, insights gained from previous experimental and modeling investigations are elucidated.

S. Oberthür (2010). This paper provides a review on two aspects that are battery thermal model development and thermal management strategies. Thermal effects of lithium-ion batteries in terms of thermal runaway and response under cold temperatures will be studied, and heat generation methods are discussed with aim of performing accurate battery thermal analysis. .

B. Dunn, H. Kamath, J.M. Tarascon (2011). Numerical simulations were performed at different discharge rates, operating temperatures and ambient temperatures of a compact Li-ion battery pack. The results show that at stressful conditions, i.e. at ambient temperatures (for example 40–45 °C), air-cooling is not a proper thermal management system to keep the temperature of the cell in the desirable operating range without expending significant fan power.

S.M. Lukic, J. Cao, R.C. Bansal, F. Rodriguez, A. Emadi (2008) Factors that influence the cooling capability of forced air cooling are discussed based on the simulations. The three-dimensional method and lumped model of single cell have been applied in the simulation. The temperature distributions of batteries are quantitatively described based on different module patterns, fan locations as well as inter-cell distance, and the conclusions are arrived [5].

H. Budde Meiwes, J. Drillkens, B. Lunz, J. Muennix, S. Rothgang, J. Kowal (2013). The experiments for model validation are conducted on a single cell of the battery pack with forced-air cooling system. The effects of longitudinal and transverse spacing on the cooling performances are analyzed for the battery pack with the aligned and the staggered arrays.

S.M.A.S. Bukhari, J. Maqsood, M.Q. Baig, S. Ashraf, T.A. Khan (2015). This paper selects the forced air cooling as the study object, it increases the contact area for thermal conduction by adding bottom duct, and the area of battery pack top exists natural convection, so the heat dissipation performance of bottom duct mode is more superior. It could reduce the SOC state or charge & discharge rate to satisfy the heat dissipation performance requirements; as considering the practical operation condition of battery pack.

M. Lowe, S. Tokuoka, T. Trigg, G. Gereffi,(2010). In this paper, a passive technique is examined by adding an inlet plenum to reduce the maximum temperature and improve temperature uniformity in a simple battery pack. The inlet plenum changes the direction of the flow and dramatically reduces the issues of air recirculation and dead-air regions between adjacent cells.

J.M. Tarascon, M. Armand (2011). In this article, a specific design of air-cooled battery system is theoretically investigated and numerically modelled to satisfy the required thermal specifications. Since a typical battery system in hybrid electric vehicles consists of the stacked multiple battery cells, cooling performance is determined mainly by the uniform distribution of air flow in the coolant passage which dissipates heat generated from the battery cells.

V. Etacheri, R. Marom, R. Elazari, G. Salitra, D. Aurbach (2011). In this paper, the cooling performance of the parallel air-cooled BTMS is improved through using the secondary vent. Computational fluid dynamics is introduced to calculate the flow field and the temperature field, finally evaluating the cooling performance of the BTMS. The analysis results demonstrate that the temperature rise and the temperature difference of the battery pack.

V. Etacheri, R. Marom, R. Elazari, G. Salitra, D. Aurbach (2011). A simplified thermal model is proposed according to the examination of various simplification strategies and validation from the detailed thermal model. Forced convection is effective in depressing the maximum temperature, and the temperature uniformity does not necessarily decrease infinitely when the extent of forced convection is enhanced.

K. Smith, C.Y. Wang, (2006). In this paper, the displaying in CREO parametric programming and examination done ANSYS. In this paper examination to decide the weight, speed, heat move coefficient, mass stream rate and warmth move rate for the various structures of lithium ion batteries.

K. Smith, C.Y. Wang, (2016). Although the energy density of Li-ion batteries exceeds that of all previous competitive batteries today's EVs are required to employ higher energy density batteries than ever before and to accumulate more cells in the pack to boost range. This tendency increases the internal heat generation and heat accumulation of the batteries, making the BTMS even more important .BTMS has been the subject of various review publications in the past. Rao and Wang (2011) began by discussing the total thermal energy management of BEVs, HEVs, and fuel cell electric cars (FCEVs).

K. Smith, C.Y. Wang, (2011). They looked into the creation of power batteries as well as mathematical models of battery thermal behaviour, which is essential for the right design of BTMS. They then analysed and classified BTMS based on heat transfer mediums :air ,liquid , and phase change material (PCM). They focused specifically on BTMS employing PCM and explored the thermos mechanical

behaviours and heat transfer enhancement of the PCM to ensure proper application in BTMS. They also carried out a complete BTMS trade off analysis following study of Garcia and Cosley (2004).

D. Pan, S. Xu, C. Lin, G. Chang,(2016). They first researched the electrochemical /equivalent circuit models of Li-ion batteries to explain heat generation and thermal runaway under sub zero temperatures. Then, similarly to Rao and Wang (2011), they conducted a review. BTMS are classified as air liquid, PCM, heat pipe and combination of these medium based on the heat transfer media. Liu and colleagues (2017) examined the BTMS employing the phase change method and the solid -liquid phase shift, as well as air based and liquid based BTMS.

H. Liu, Z. Wei, W. He, J. Zhao(2017). The thermal behaviours of the battery at the cell level, including the quantity of heat generated, heat transmission techniques and thermal boundary conditions were researched, while various BTMS were investigated at the module level. They specifically examined the efficiency of air -based BTMS with liquid based BTMS depending on cell configuration (serial, parallel, and mixed) and sub categories the indirect liquid cooling system is divided into tube cooling and plate cooling. Mini/micro-channels. Previous BTMS review papers primarily focused on depending on the heat exchange method or materials unlike the various research there was little debate on the battery temperature concerns, on BTMS future direction as a result, various BTMS in terms of thermal cycle options have been thoroughly examined and the following generation BTMS has been Developed.

CHAPTER 3

METHODOLOGY

3.1 TYPES OF COOLING

- Phase change material absorbs heat energy by changing state from solid to liquid. While changing phase, the material can absorb large amounts of heat with little change in temperature.

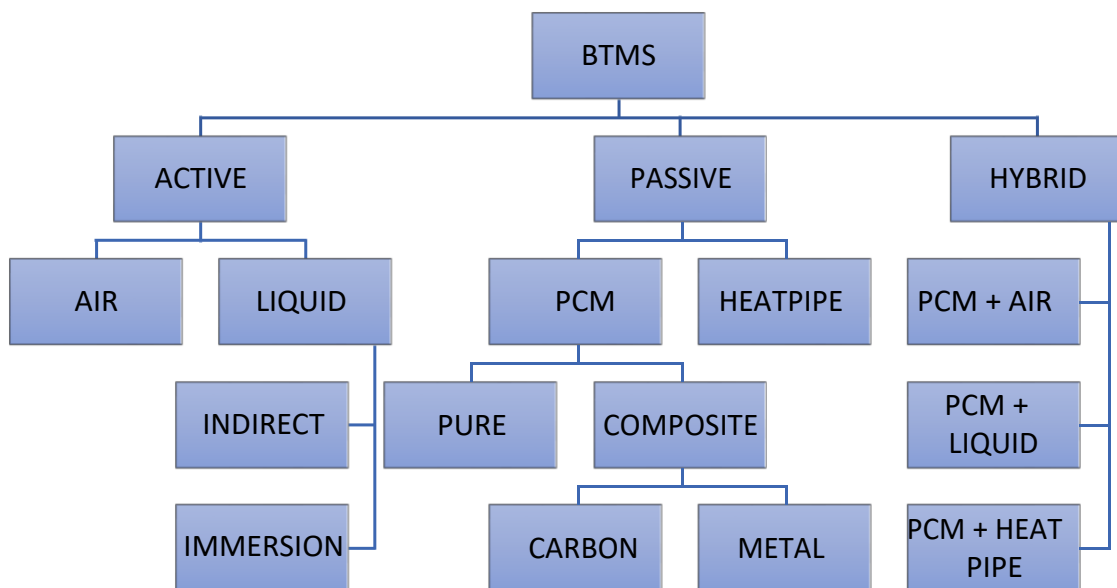


Fig 3.1: Flow Chart of Cooling Method.

- Cooling fins increase surface area to increase the rate of heat transfer. Heat is transferred from the battery pack to the fin through conduction, and from

the fin to the air through convection. Fins have high thermal conductivity and can achieve cooling goals, but they add a lot of additional weight to the pack.

- Air cooling uses the principle of convection to transfer heat away from the battery pack. As air runs over the surface, it will carry away the heat emitted by the pack. Air cooling is simple and easy, but not very efficient and relatively crude compared to liquid cooling.
- Liquid coolants have higher heat conductivity and heat capacity (ability to store heat in the form of energy in its bonds) than air, and therefore performs very effectively and own advantages like compact structure and ease of arrangement.
- Out of these options (fig:3.1), liquid coolants will deliver the best performance for maintaining a battery pack in the correct temperature range and uniformity.

3.2 METHODOLOGY

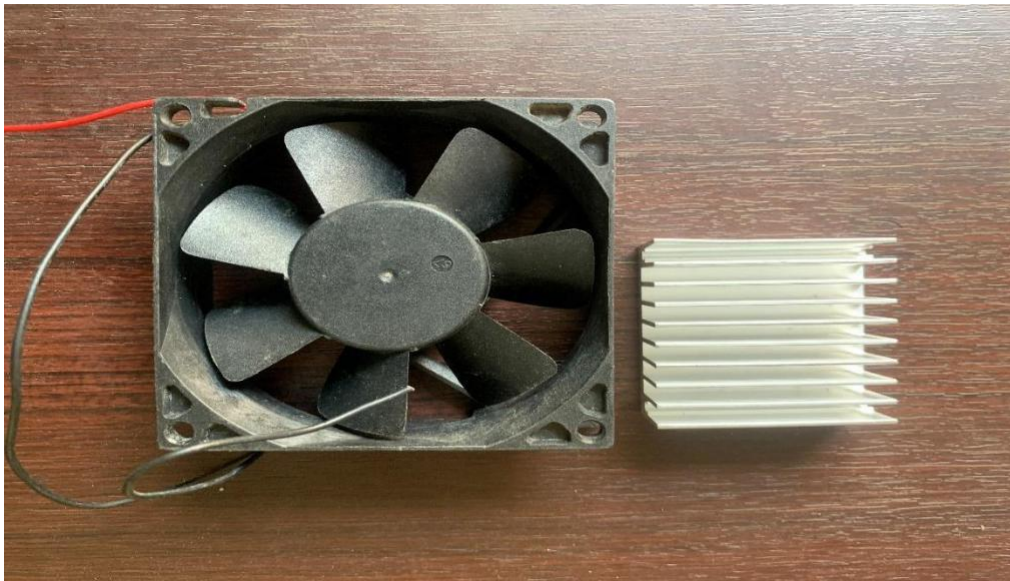


Fig 3.2: Exhaust

Our aim is to make passive cooling of the battery , by placing the battery in the aluminium bar .One side of the aluminum bar a small tube is made to flow of coolant through it , to cool the cell And the other side of the battery is fixed with thermoelectric generator .The coolant passing through the hole in the aluminum bar cools the battery temperature by passing through the metal. Aluminium bar is used to equally spread the heat produced from the battery. The liquid passes into the aluminium bar collects the heat from the battery and the liquid is cools using radiator. The liquid cools easily by radiator (fig:3.2) , while the vehicle is in motion without any fan. But while charging , we need an external forced cooling for radiator such as fan. The power supply for the radiator fan is produced using the Thermoelectric Generator placed on the other side of the battery . As well as , we can use the power generated from the thermoelectric generator for the pump to circulate the water inside the copper tube and radiator loop.

Table 3.2 : Properties of Density in Battery

Mass Energy Density	100 – 180 WH/kg	Self Discharge Rate	1 – 5% / month
Volume Energy Density	200–300WH/L	Cycle Durability	500 – 15000 cycles
Power Density	1000 – 5000 W/kg	Typical Cost	\$0.50 - \$2.50 /WH
Charge/Discharge Efficiency	95 – 99%	Mass Energy Density	100 – 180 WH/kg

3.3 PROCESS FLOW CHART

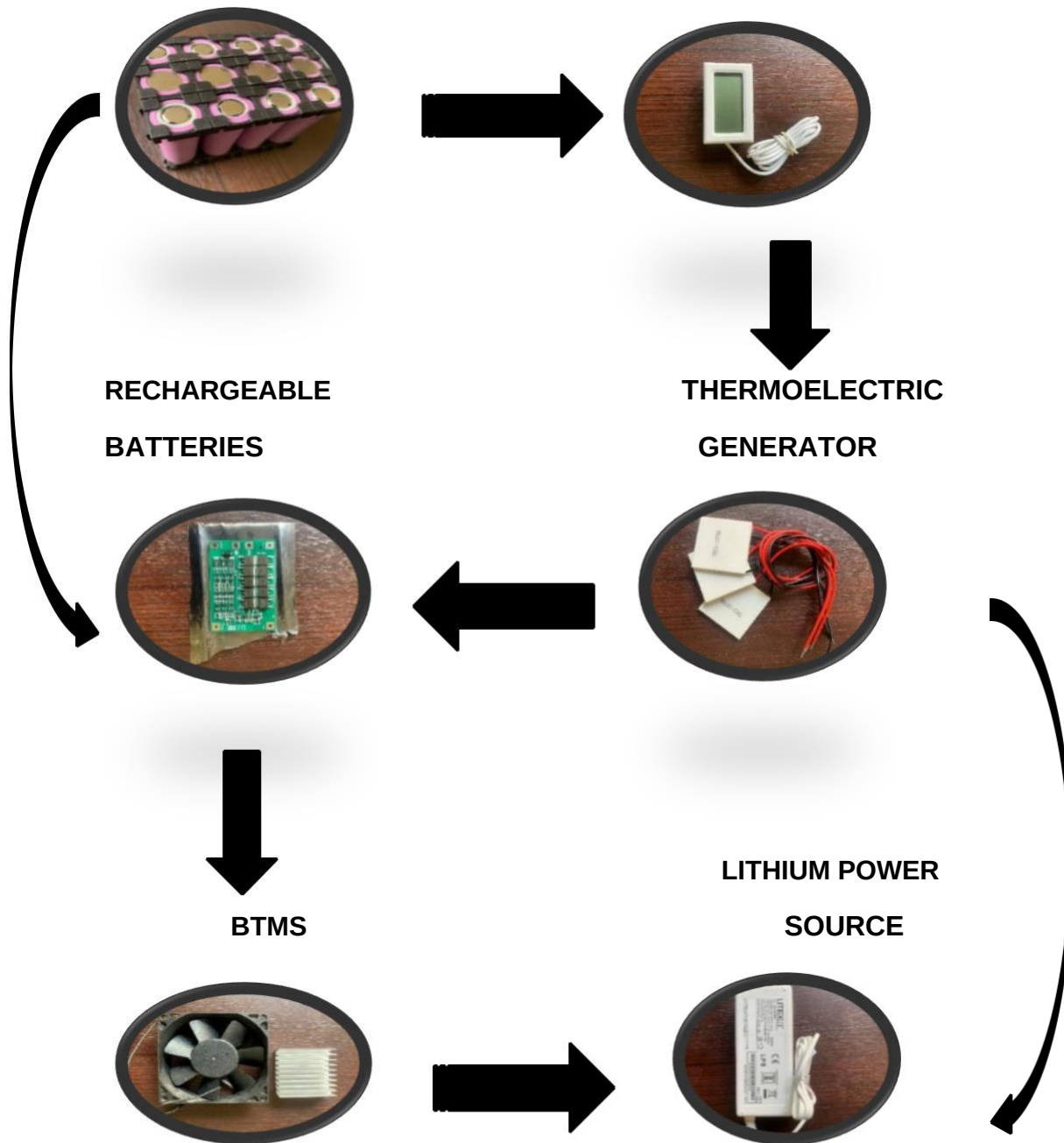


Fig 3.3: Flow chart Overview of BTMS

3.4 PASSIVE COOLING TECHNIQUE

Passive cooling decreases the power consumed by the devices in a thermal zone. Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption. We can use passive cooling method as we use thermoelectric Generator to get power to run the radiator fan And water pump the circulate the water. The advantages of passive cooling techniques lie in the energy efficiency and lower financial cost as shown in fig (3.4).

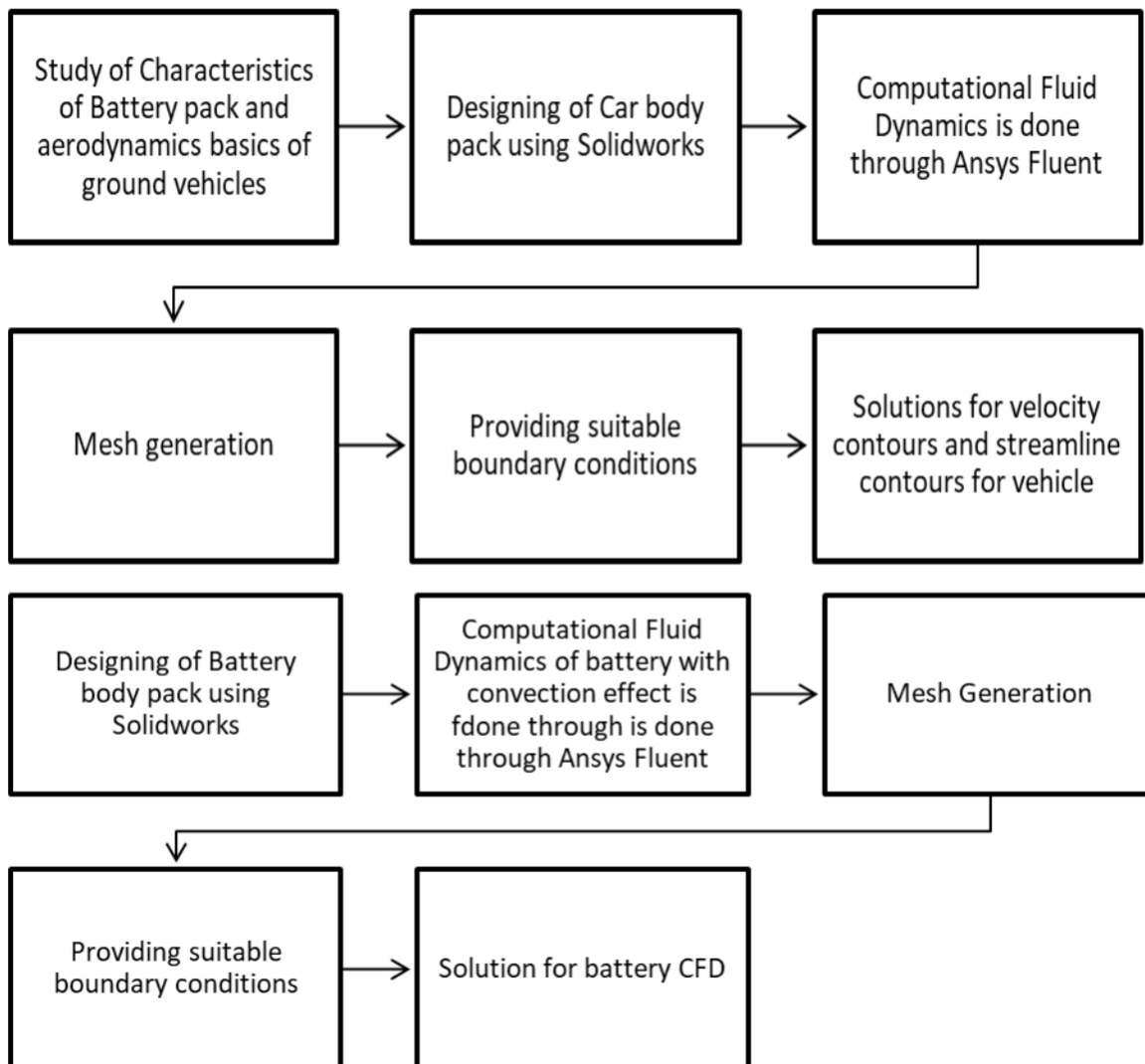


Fig 3.4 : Passive Cooling Method

3.5 BATTERY CONFIGURATION



Fig 3.5 : Rechargeable Battery

- Lithium ion cell - **18650** (fig:3.5)
- Battery Voltage: 3.7V
- Capacity: 3000 mAh
- Shape : Circular
- Battery Dimension:
Height =65mm , Diameter =18mm
- Weight : 45 g
- **Energy 4.44 Wh** • Temperature limits charge : 0~45°C discharge :
-20~60°C

CHAPTER 4

EXPERIMENTAL PROCEDURE

4.1 CAD MODELS

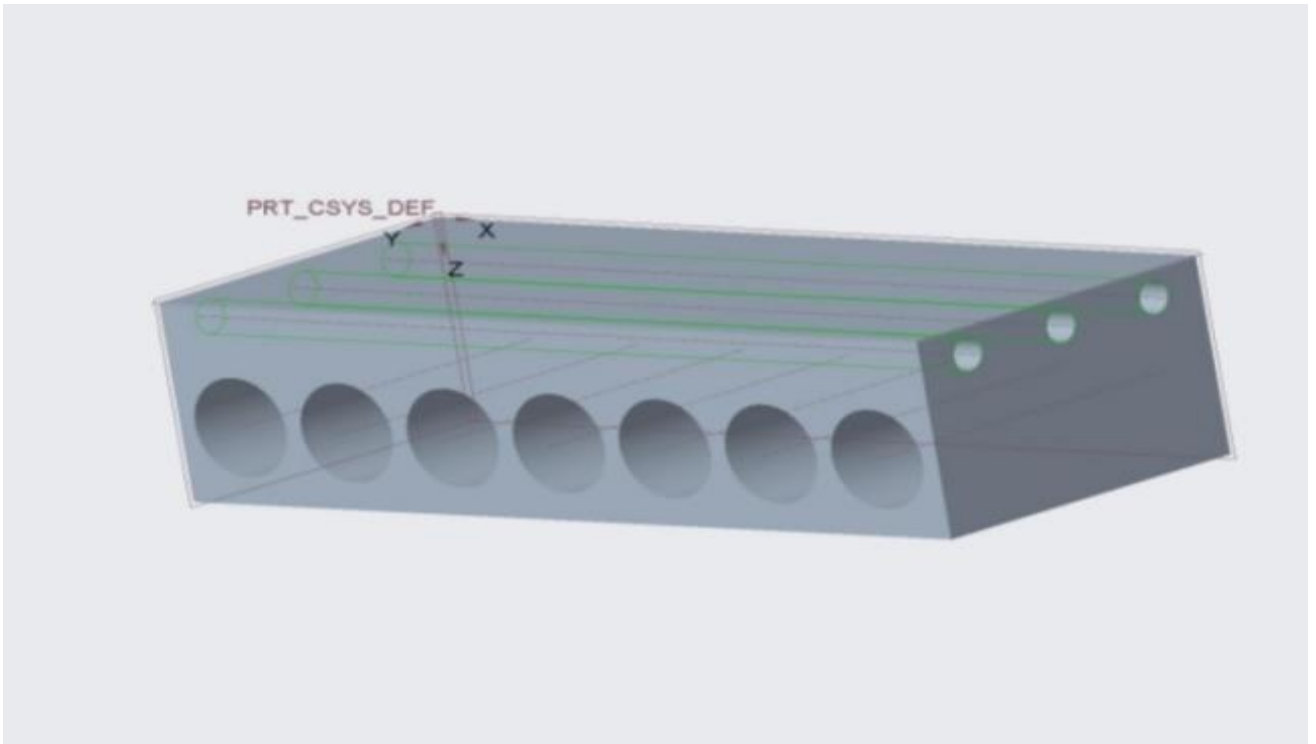


Fig 4.1: Working Model

4.2 TEMPERATURE ANALYSIS

4.2.1 WHILE CHARGING:

We have examined the temperature produced from the battery while charging without any cooling technique . We have placed the thermocouple in three different places on the battery . From that , we have analyzed the battery

temperature while charging and It temperature raises upto (in fig 4.2.1) 56.6 degree Celsius while continuous charging for 4 hours.



Fig 4.2.1 : Power source

4.2.2 WHILE DISCHARGING:

We have examined the temperature produced from the battery while discharging without any cooling technique as shown in fig:4.2.2. We have placed the thermocouple in three different places on the battery . From that , we have analyzed the battery temperature while discharging and it raises upto 52.6 degree

Celsius while discharging by 1C , 2C and 3C connection for 4, 2 and 1.15 hrs respectively .

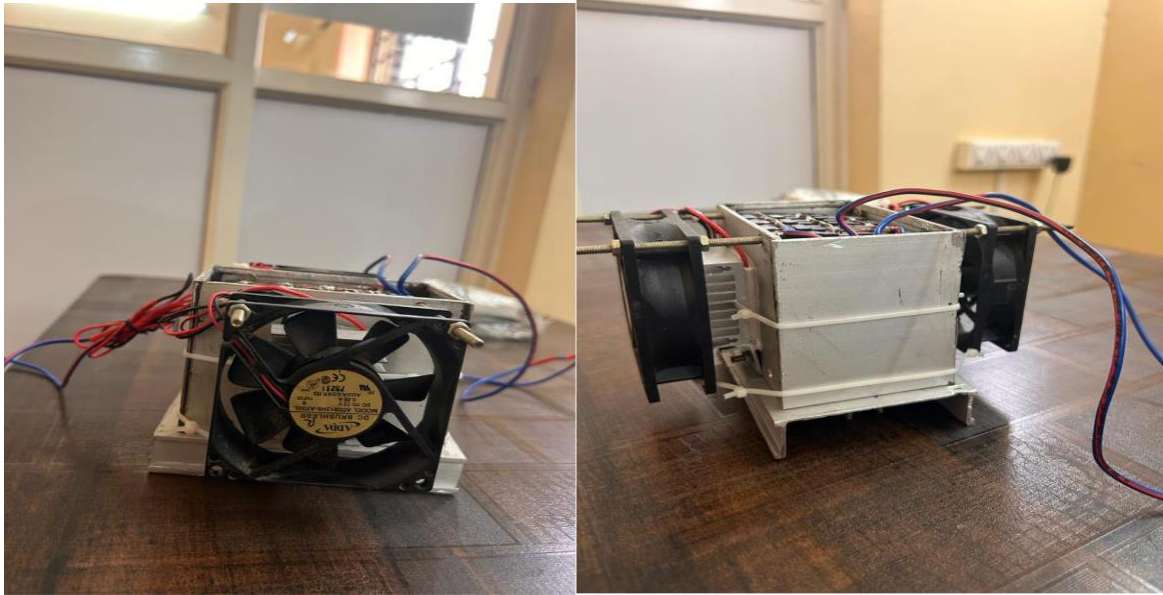


Fig 4.2.2: Charging and Discharging

4.3 ANALYSIS PROCEDURE

- Open the Ansys workbench software and select the CFX (Fluent) option.
- Give the preferred properties in the properties tab which is showed in the table (4.3).
- Select Geometry and select design modular option for importing the geometry that we have done Solidworks software.
- Import the model in iges format .
- In design modular tab , Select tools within which select the enclosure tab and give dimensions

Details View	
Details of Enclosure1	
Enclosure	Enclosure1
Shape	Box
Number of Planes	0
Cushion	Non-Uniform
☐ FD1, Cushion +X value (>0)	3 m
☐ FD2, Cushion +Y value (>0)	2 m
☐ FD3, Cushion +Z value (>0)	3 m
☐ FD4, Cushion -X value (>0)	3 m
☐ FD5, Cushion -Y value (>0)	1 m
☐ FD6, Cushion -Z value (>0)	3 m
Target Bodies	All Bodies

Table 4.3: Analysis on Ansys

- Select create option and select Boolean operation . Subtract the body of the car from the enclosure and make it a single body .
- Select Section plane option and draw a line which will disscet the whole body into required parts.

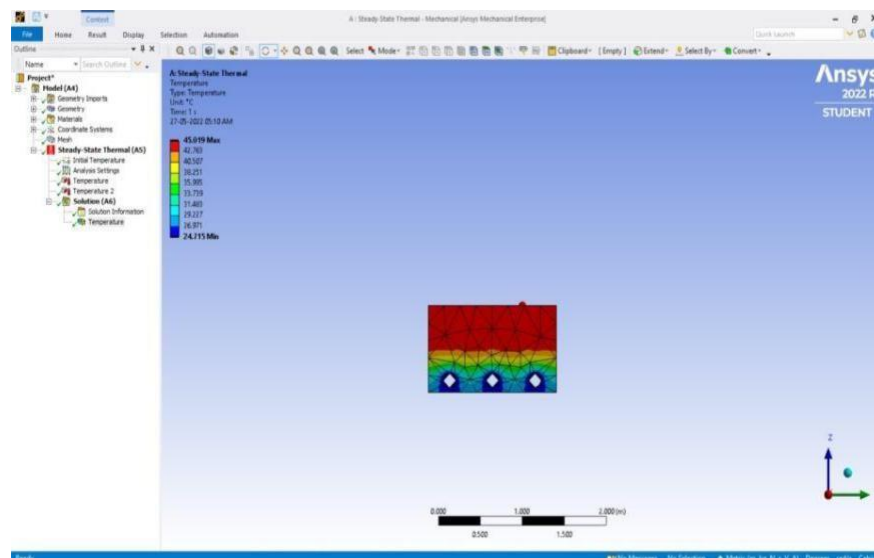


Fig 4.3: Front View of the model

- Then Select tools and select symmetry and click on the symmetry plane and generate it .

4.3.1 Meshing :

- Select Mesh tool and Select patch conforming method and select tetrahedrons shape .
- Generate mesh and small mesh will be created around the corners and large mesh around enclosure .
- Select the sides individually and select named selections and name it.
- Change to the wireframe mode in ansys as shown in the fig:4.3.1.

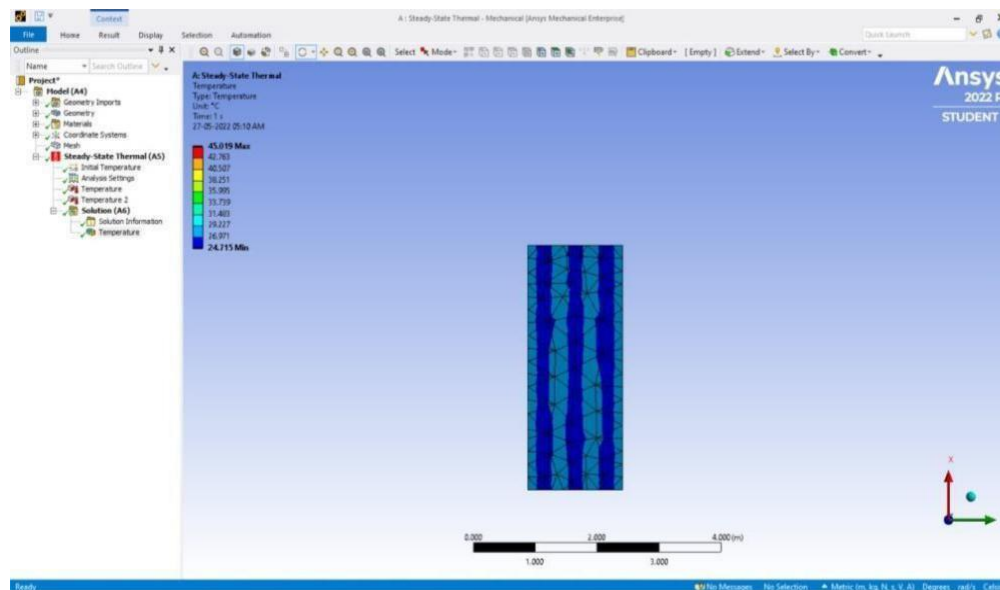


Fig 4.3.1 : Top View of the Model

- Check the named selections and Update the mesh before leaving .

4.3.2 Setup :

- Select the preprocessor settings in the setup box (fig:4.3.2)
- Select the solver mode to be Pressure based. The velocity formulation is absolute.
- Select the energy equation mode and Select viscous SST- k -omega ☐
Select the materials and enter fluid as air and solid as aluminium .

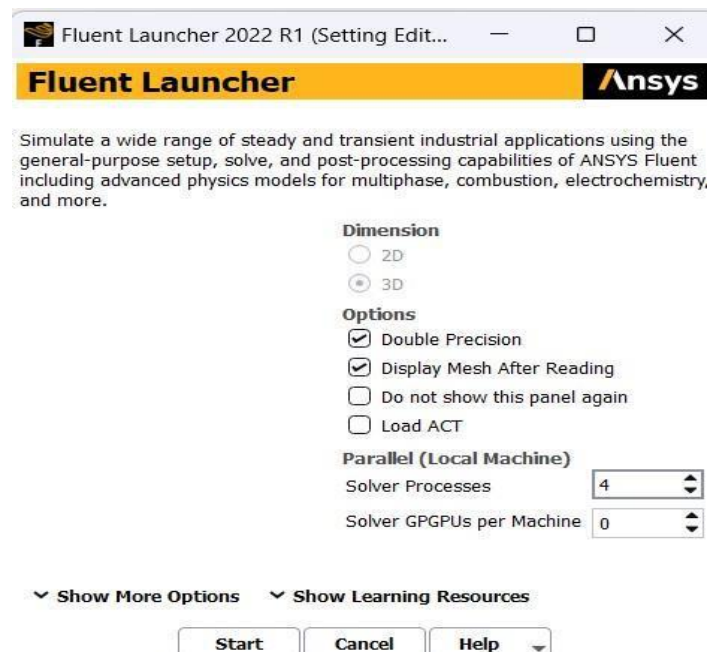


Fig 4.3.2 : Setup Box in Ansys

- ✓ Select the boundary conditions and select inlet as velocity inlet and outlet as pressure outlet .
- ✓ Select symmetric plane and generate.
- ✓ Select solution in setup and select coupled scheme and second order upwind momentum and pressure .
- ✓ Then select Initialization and select standard initialization and compute from inlet and apply it .

- ✓ Run calculation and give 100 iterations . The residuals curve is plotted . The residuals graph should be a downward graph.

4.3.3 Result :

- ✓ Select Location and click new plane and name it . Select the suitable plane for symmetry as fig 4.3.3
- ✓ Select the contour and select the suitable position (plane or body) . Select User specified range And give the maximum and minimum velocity values .
- ✓ Select the digital legend view . Select Appearance and give it fixed range .
- ✓ Select Vector and enter the location and name it . Give the direction as forward direction
- ✓ Select streamline and start from the inlet . Give the number of lines as 250. Select the direction as forward .

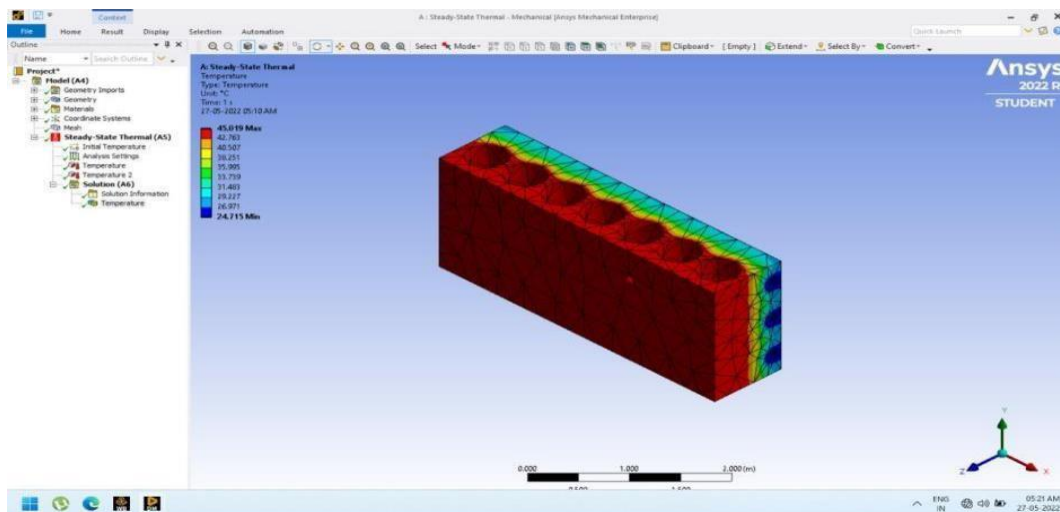


Fig 4.3.3 : Side View of the Ansys Model

4.4 THERMOELECTRIC GENERATOR

In this thermoelectric generator, The hot side is maintained at 65°C and the cold side is maintained at 27°C. With this temperatures, we get an output voltage of 0.24v per TEG. We have used 12 batteries, so we got a overall output of $9 \times 0.24 = 2.16$ V. Passive cooling decreases the power consumed by the devices in a thermal zone. Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption. We can use passive cooling method as we use thermoelectric Generator to get power to run the radiator fan And water pump the circulate the water. The advantages of passive cooling techniques lie in the energy efficiency and lower financial cost. Our aim is to make passive cooling of the battery, by placing the battery in the aluminium bar. One side of the aluminum bar a small tube is made to flow of coolant through it, to cool the cell. And the other side of the battery is fixed with thermoelectric generator. The coolant passing through the hole in the aluminum bar cools the battery temperature by passing through the metal.

Aluminium bar is used to equally spread the heat produced from the battery. The liquid passes into the aluminium bar collects the heat from the battery and the liquid is cools using radiator. The liquid cools easily by radiator, while the vehicle is in motion without any fan. But while charging, we need an external forced cooling for radiator such as fan. The power supply for the radiator fan is produced using the Thermoelectric Generator placed on the other side of the battery. As well as, we can use the power generated from the thermoelectric generator for the pump to circulate the water inside the copper tube and radiator loop. Each battery is cooled by two method on either side of the 18650 battery. One side is cooled by liquid flowing through the copper tube. And the other side of the battery is indirectly cooled by thermoelectric generator, by absorbing the heat from the battery. And the Thermoelectric generator produces DC voltage by absorbing the heat of the battery on one side and the cooling from the liquid

flowing through the copper tube. Temperature of the battery with Btms raises upto 39.5, while charging. Temperature of the battery with Btms raises upto 35.5, while discharging.

- ✓ In this thermoelectric generator (fig:4.4), , The hot side is maintained at 65°C and the cold side is maintained at 27°C.
- ✓ With this temperatures , we get an output voltage of 0.24v per TEG.
- ✓ We have used 12 batteries , so we got a overall output of $9 \times 0.24 = 2.16$ V.



Fig 4.4 : Thermoelectric Generator.

4.5 COOLING METHOD

- We are cooling the battery by passing the coolant through the hole in the aluminum bar.
- Coolant can be of water or ethylene glycol.
- The heat generated from the battery is transferred to the aluminum bar.
- The water absorbs the heat from the aluminium bar , and thus cools the bar , which intends cools the battery by reverse cooling method.

CHAPTER 5

CALCULATIONS

5.1 CHARGING TIME

Battery – 12 V , 20 Ah

- Charger – 12 V , 5 Ah

Here,

Time= Battery/Charger.

$T = \text{BatteryAh} / \text{chargerAh}$

$$= \frac{20}{5} = 4 \text{ hrs.}$$

- Battery – 12 V , 20 Ah
- Charger- 12V , 7.5 Ah

$T = \text{battery Ah} / \text{Charger Ah}$

$$= 20 / 7.5 = 2.6 \text{ hrs.}$$

- Battery – 12V , 20 Ah

- Charger – 12V, 12 Ah

$T = \text{battery Ah} / \text{Charger Ah}$

$$= 20 / 12 = 1.6 \text{ hrs.}$$

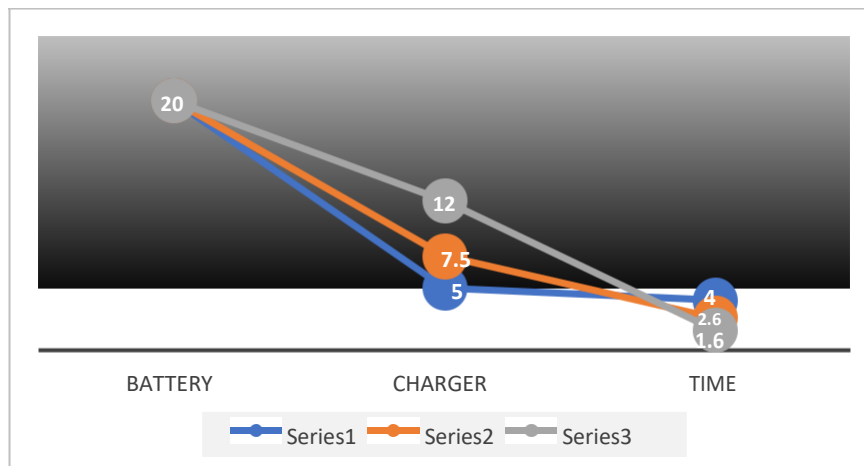


Fig 5.1 : Charging Time Graph

5.2 DISCHARGING TIME

- Bulb load = 60 W = 60/12 = 5amps

- Discharge rate : 5 amps 1C =>

$$20/\text{time}=5\text{amps}$$

=4 hrs.

$$2C = 2 \text{ hrs.}$$

$$3C = 1.33 \text{ hrs.}$$

5.3 HEAT GENERATED

- $Gr = 1.015 \times 10$

- $Pr = 0.691$

- $Ra = Gr \times$

$$Pr = 0.702 \times 10$$

- $Nu = 17$; then $h = 7.2$

- Heat generated from 1 cell:

$$Q = h A (T_1 - T_2) \text{ -----EQ 1}$$

$$= 7.2 \times 3.14 \times 0.018 \times 0.065 \times (60 - 25)$$

$$= 0.92 \text{ J/s}$$

Where ,

h=7.2

T2 = battery max

temp T1 = 60

- For 1 cell :

$$= 3.7 \times 3$$

$$= 11.1 \text{ W}$$

- For 21 cell (overall pack) :

$$P = V \times I$$

$$= 11.1 \times 21$$

$$= 233.1 \text{ W}$$

5.4 MASS FLOW RATE

$$Q = \dot{m} \times C_p \times (T_2 - T_1) \text{ ----- EQ 2}$$

Where , sub cp of water in eq 2,

$$C_p \text{ of water} = 4180 \text{ J/kg}$$

$$Q = \dot{m} \times C_p \times (T_2 - T_1) \text{ -----EQ 2}$$

Where , Sub eq 1 in eq2 so,

$$C_p \text{ of water} = 4180 \text{ J/kg K}$$

$$T_1 = 20 ; T_2 = 40 ; Q = 19.32.$$

$$\dot{m} = \frac{Q}{C_p \times (T_2 - T_1)} = 2.31 \times 10^{-3} \text{ kg/s. (overall } \dot{m} \text{)}$$

$$C_p \times (T_2 - T_1)$$

$$\Rightarrow 7.7 \times 10^{-3} \text{ kg/s (for 1 Al bar , 7cell) .}$$

CHAPTER 6

6.1 CONCLUSION

The charging and discharge rate , inlet water temperature and velocity are varied conditions. The Thermal analysis of battery module of 18650 Lithium-ion cells has been conducted to analyze and optimize the design of the battery thermal management system . The temperature reduction is analysed with the help of ansys software. The charging time and the discharging time is calculated for the specified capacity charger and loads. The heat generated from one cell and whole battery pack is calculated . The mass flow rate of the water is calculated by varying the value and the temperature difference for different mass flows. The CAD model is analyzed using ANSYS software . the thermal analysis is done on the aluminium bar , and the thermal variations are analyzed .

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