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Analysis of Thermal Performance of Various Battery Packs and Materials Used in Electric Vehicles: A Review

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Electric powered vehicle popularity gives us better option for reducing the hydrocarbon emissions for the clean environment and will help to minimizing the troposphere of ozone degradation. Evs that are powered by batteries are becoming more commonplace worldwide. A strong Battery Management System (BMS) is essential for the reliable and safe operation of batteries, which have been widely used in many large power applications, including EVs and hybrid EVs. Their optimal plan and the management are significant for safe and beneficial tasks. This review paper examined with about the oldest kind of battery-latest powered battery (Pb-acid battery) and the most recent innovation of battery, lithium-ion battery. The present paper deals about the recent improvement in three important areas like Battery pack shape, different battery material and thermal behaviour which covered main challenges for EVs operation.

Keywords: *Battery, Battery Management, Battery Material, Battery Pack, Electric Vehicles, Thermal.*

1.0 Introduction

People started to discover for ecofriendly vehicle that could be powered by alternate rechargeable energies as a result of public awareness of the world's finite supply of fuel energy and the production of greenhouse gases by internal combustion engine vehicles[1]. The concept of an electric vehicle was not made widely known until 1859, despite the fact that electricity is a sustainable energy source for vehicle motors. Batteries are crucial to the progress of electric vehicles since they contains a portable object which accumulate electric power in order to power their motors. Electric mobility is one of the areas that utilize power, which is a battery-powered energy source. Electric versatility eludes to all road vehicles that utilization an electric engine and are fuelled completely or part of the way by power. Electric mobility incorporates vehicles with a simply electric engine (Electric Vehicles - EV), vehicles with a little burning motor and an electric engine (Range Extended Electric Vehicles - REEV), and vehicles with a traditional gas powered motor and an electric impetus framework. The automobile vehicles developed in the electric mobility sector rely on electricity accumulated in the batteries to power their systems. Because automobile cars utilize electric power to run their electric motors, results in zero emission of harmful gases from them, as there is no combustion in the system, as there is with internal combustion engines[2]. Market is very competitive to create better and cost-effective electric powertrains to suit these rising needs for HEV/EV applications. In such development endeavours, the potential payback is immense, as are the business risks of going to market with defective, insufficient, or suboptimal designs[3]. Clearly, a technological revolution is taking place in the automobile industry. The responsibility of leading the charge has been put largely on car engineers, who must radically rethink their approach to powertrain design. The challenge for engineers at automakers and

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suppliers of main subsystems and components is to do a significant amount of research and development on a totally new generation of powertrain in a very short period of time. Leading automotive businesses with HEV/EV ambitions are relying on simulation-driven development rather than antiquated techniques of trial-and-error prototype testing to satisfy these objectives[4]. Indeed, in the competition to create the next generation of enhanced electric powertrains, successful adoption of advanced numerical simulation will likely differentiate winning businesses from less capable competitors. When an Internal Combustion Engine (IC Engine) is replaced with an electric engine that is fuelled by energy stored in batteries and restricted by a power electronic footing inverter that is when electric vehicles will be at their optimum. The electric engine is a very efficient engine since it controls the vehicle with 90–95 percent of the information energy[5]. The electric engine is driven by the way that it controls the electric vehicle with electrical energy put away in batteries[6-9]. EV deals have been stale for the beyond two years, averaging 2000 units every year[10]. Regardless, by 2030, there is an objective of having a 100% electric vehicle armada, and starting around 2020, the yearly development rate is 28.12%. Reva (Mahindra), India's most memorable electric vehicle, was uncovered in 2001 and is supposed to sell a couple of units from that point forward[11-13]. In 2010, Toyota launched the Prius hybrid, which was followed in 2013 by the Camry hybrid. In a few metropolitan locations, hybrid and electric cars have been tested as a preliminary project.

2.0 Traction Battery

One of the crucial components of the electric was the traction battery. Traction batteries are mostly used as power sources for equipment powered by mechanical source, industry vehicles, and road vehicles. Electric Vehicle Battery (EVB) is another name for the rechargeable traction battery. Unlike auxiliary batteries, traction batteries sustain the complete electric vehicle rather than simply supplying the energy required to start the engine.

3.0 Battery Management System in EVs

Typically, the voltage and capacity of the battery cell utilised in EVs are constrained. Therefore, it is necessary to first bundle and combine the individual battery cells into a battery module. One or more modules may be present in an EV's battery system, depending on the situation. Thousands or hundreds of single cells make up the standard battery system. Controlling that many cells requires the Battery Management System (BMS). Figure 1, depicts the link between these important technologies. An effective battery model is necessary for the analysis of battery behaviour, battery state monitoring, real-time controller design, temperature management, and fault diagnosis. Additionally, although they are essential for regulating the functioning of batteries, several internal battery states that cannot be detected directly. Therefore, these states need to be tracked using the appropriate estimate methods.

We assume the broad perspective that BMS refers to any system that controls the battery in accordance with [16]. Any type of technology or equipment, including mechanical or electrical systems, might be used in the system. A single cell, battery module, or battery pack

Table 1. Different types of batteries used in EVs[14]

Battery description	Working life/cycle	Energy content/ ($W.h.kg^{-1}$)	Charger effectiveness (%)	Rate of self-discharge (% $month^{-1}$)
Li-ion battery	600–3000	100–270	80–90	3–10
Lead acid battery	200–300	30–50	50–95	5
NiCd battery	1000	50–80	70–90	20
NiMH battery	300–600	60–120	65	30

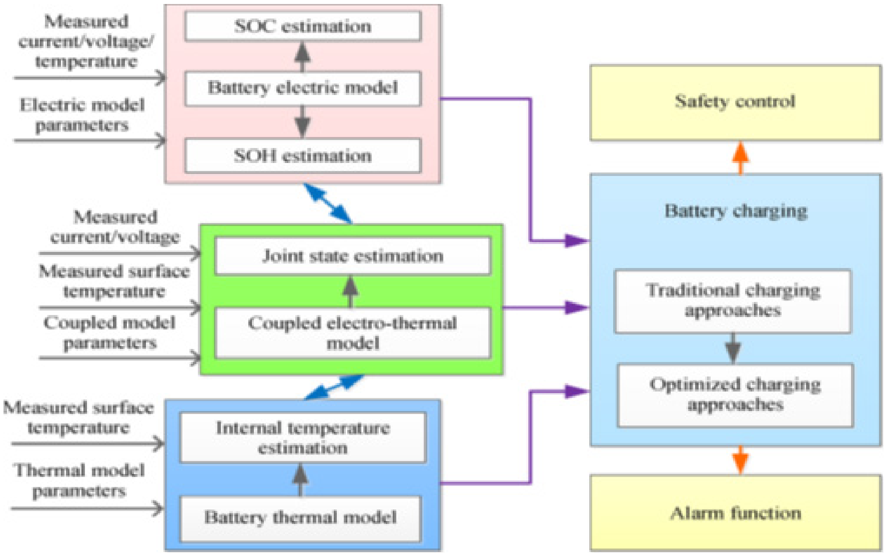

Figure 1. Link between the important technologies in battery management system[15].

might make up the battery. It could also be rechargeable or not.

The system may control the battery by keeping track of it, evaluating its status, safeguarding it, providing data, balancing it, etc.

The BMS in cars is made up of many types of sensors, actuators, and controllers with different algorithms and signal lines. The following are the top three responsibilities of the BMS in cars.[19]

- To guard against harming the battery packs and cells.
- To ensure safety, extend the batteries' service life, and ensure that they perform within the right voltage and temperature range.
- To keep the batteries functioning so that they can meet the needs of the cars.

4.0 Major Challenges in EVS Battery

- Battery packs
- Battery thermal management system
- Battery's material
- Safety major concern
- Life cycle of the battery
- Charging time
- High capital and operating costs
- Renewal of batteries

4.1 Battery's Pack

In HEV/EVs, electric batteries have a dual purpose: they provide primary driving power for the vehicle as well as energy for a variety of electric-powered auxiliary systems. As a result, they must fulfil the same requirements and expectations as petroleum-fuelled automobiles in terms of dependability, durability, and cost — plus they must supply orders of magnitude more energy than ordinary batteries[20]. Engineers must consider the temperature, structural, and electromagnetic effects on the battery pack as well as the cells therein when designing batteries with huge energy capacities and higher power output. Batteries, for example, produce heat while charging and discharging. The temperature of each cell in the battery pack must be kept within a few degrees Celsius of one another. Otherwise, dangerous internal current loops might build within the pack, reducing battery life dramatically. This demands a cooling system — whether air or liquid — and might also provide the additional difficulty of reducing noise near the passenger compartment. HEV/EV drivers are accustomed to ultra-quiet driving, which is incompatible with a noisy cooling system.

4.2 Battery Thermal Management System (BMS)

Because the usage of electric vehicles is expected to grow in the near future, producing efficient batteries is a top priority. Thermal deterioration of the batteries is a significant barrier for improving BTMS, which has an impact on the EV's range[21]. The BTMS's main goal is to regulate the battery cell's temperature in order to increase the battery's lifespan. Electric cars frequently employ lithium-ion batteries as energy storage. Several barriers exist, such as less performance at extreme temperatures, lower electrode working at higher temperatures, the explicit influence on vehicle efficiency as well as safety worries in lithium ion types batteries. As a result, one of the key technologies for an electric vehicle's long-term success is an outstanding thermal battery management system. For Li-ion batteries, operating temperatures between 25 and 40 degrees Celsius are excellent, when the batteries' temperature reaches a specific point.

4.3 Battery's Material

Various kind of battery's used in current scenario in the market:

- Lead-acid battery
- Nickel Cadmium Battery (NICD)
- Nickel Metal Hydride Battery (NIMH)
- Lithium-ion battery

In electrified cars, lithium-ion batteries are one of the most used energy storage systems. Because of their tremendous power and energy density, one of the key concerns of their uses is safety. Abuse tolerance tests such as nail penetration, 1 over-charge 2, and thermal-ramp3 testing were formerly used to assess the safety of various battery types. These tests can offer pass/fail information on battery abuse tolerance performance under various situations, but they are generally expensive and time intensive to run on large scale batteries.

4.4 Safety Major Concern

The electric vehicle must adhere to state or local regulations on safety. The batteries must be able to withstand a variety of situations, including overcharging, temperature changes, short circuits, fire impacts, vibration, humidity, and submersion in water. These vehicles should be built with safety features including destructible terrain, short - circuiting, and shielding from high voltage lines.

4.5 Life Cycle of the Battery

Electric motors, batteries, chargers, and controllers are commonly used to create electric cars instead of a gasoline engine and fuel tank. EV batteries gradually deteriorate since they are made to endure for a very long time. Currently, the vast majority of battery producers provide an 8year/100,000-mile warranty.

4.6 High Capital and Operating Costs

Battery packs for electric vehicles are expensive and need to be changed frequently throughout their lifetime. Gas-powered vehicles are less costly than electric vehicles[22-23].

(a) Perception of customers
(b) Batteries' raw ingredients

5.0 Findings from the Previous Work

In current section we will discussed about the previous research on basically three areas which is,

Table 2. Literature review on Battery thermal management using various techniques

Sr. No.	Reference	Year	Area of work	Outcomes
1.	Goel *et al.*,[24-25]	2021	BTMS (Battery Thermal Management System)	The paper discusses several modelling techniques and optimization methods used in research on the market potential rates of battery-operated, hybrid, and plug-in hybrid electric vehicles.

Table 2 Continued

2.	Katoch *et al.*,[26]	2020	Battery Thermal Management System using various techniques	This review study examines several battery thermal management systems, including air, liquid, direct refrigerant, phase change material, thermoelectric, and heat pipe cooling, as well as potential for development.
3.	Ma *et al.*,[27]	2020	Algorithm and Simulation-dependent optimization of EV battery	The following conclusions are reached: 1. The maximum temperature and temperature differential in the battery pack may be greatly reduced by using reasonable air inlet/outlet angle and battery spacing tolerances. 2. The battery pack's maximum temperature is 34.05°C with the structural parameters decreased to 2.79°C from the initial value of 36.84°C. The difference in temperature is 3.53°C, down from 6.43°C (the original structure).
4.	Saqli *et al.*, 2020[28]	2020	Identification of the electric model and battery pack thermal modelling and simulation using COMSOL Multiphysics	The two main objectives of this work were to develop an air-cooled battery thermal pack with parallel linked cells in order to build an electrochemical-thermal model and determine the parameters and to analyse the impact of produced heat on battery performance. Modelling was carried out using COMSOL Multiphysics.
5.	Kadlag *et al.*,[29]	2019	Battery thermal management	Battery management, AC-DC and DC-DC converters, fast charging, and pulse charging are all covered in this review study. According to the research, quick pulse charging is a crucial issue for the commercialization of electric vehicles in order to keep charge times within reason.
6.	Rao *et al.*,[30]	2015	Battery heat management using paraffin/copper foam as PCM	In this study, an experimental investigation of a paraffin/copper foam as PCM, battery heat management system for an electric vehicle is presented. The maximum temperature and local temperature differential of the battery module with paraffin/copper foam were less than 45 °C and 5 °C, respectively. The maximum temperature and local temperature differential in the road operating condition were less than 40°C and 3°C, respectively, after the battery thermal management system was installed in the electric vehicle.

Table 2 Continued

7.	Fazel *et al.*,[31]	2019	Simulation of Parallel Hybrid Electric Vehicle (HEV) using matlab/ simulink-based software	Parallel Hybrid Electric Vehicle (HEV) is being researched to reduce fuel consumption and emission rate by regulating the power component rating, extending the driving range, and enhancing battery pack performance. The simulation of the HEV are performed using matlab/simulink-based software.
8.	Zhang *et al.*,[32]	2019	Simulation of thermal characteristics of lithium batteries for electric vehicles	The CFD approach is used to model and study the thermal properties of lithium batteries under natural convection, forced air cooling, and water cooling.

Table 3. Literature review considering cell arrangement and material selection

Sr. No.	**Reference**	**Year**	**Area of work**	**Outcomes**
1.	Uzair *et al.*,[33]	2021	Cell balancing in MATLAB/Simulink with an 8 cell battery balancing technique	The outcome demonstrates that for electrical vehicles using lithium-ion batteries, the active cell balancing technique is preferable to passive balancing.
2.	Raharjo *et al.*,[34]	2020	Thermal analysis of modular battery pack using passive or active cooling method	The finding shows that the Battery cell temperatures can be lowered by 10% with water cooling and 6.1% with an aluminium heat sink design.
3.	Kanga *et al.*,[35]	2020	Comparative analysis of cell arrangement using different square and rectangle shapes	The following points were supported by this study as being crucial. (1) The interior cooling effect of the battery pack varies depending on its shape. (2) If the Rayleigh number is met, conduction rather than convection as a method of heat transmission predominate in the air layer inside the battery pack.
4.	Deng *et al.*, [36]	2018	Battery simulations composite shell element Multi-Physical Modeling computational	Composite Tshell elements is more numerically stable and can achieve comparable results with much less time in multi-physics models that couple mechanical, EM and thermal solvers

1. Thermal Management of the Battery and Safety major
2. Battery Material
3. Battery pack arrangements

6.0 Conclusion

This paper reviews crucial technologies in the battery cell maintenance, particularly in the areas of thermal battery management, cell arrangement, battery charging and battery material. In order to show a hologram of the battery's operational condition in the applications of EVs, battery modelling and estimates of the battery's internal states and properties are crucial. After identifying these crucial states, an appropriate battery charging strategy may be developed to safeguard the battery against damage, increase the effectiveness of energy conversion, and increase battery lifetime. However, the majority of the BMS's main technologies are developed and verified under certain test circumstances. It is challenging to ensure the modelling, estimate, and recharging performance in actual systems that might vary from the test settings, especially in a worst-case situation. To solve this difficult problem, it is thus necessary to investigate the constraints or to create a confidence interval for the provided techniques and approaches.

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