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Analysis of Different Types of Batteries In Electric Vehicle

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Abstract - *In the modern automotive industry, Battery powered Electric Vehicles are beginning to play an important role. The construction of today's electric vehicles uses a variety of batteries, making it difficult to select one that best satisfies all the key requirements from various perspectives, including energy storage effectiveness, constructive qualities, cost price, safety, and utilisation life. The battery is the main part of an EV. This report provides a succinct overview of the various battery types utilised in electric vehicles. Electric vehicles mostly use lithium-ion, nickel metal hydride, and lead acid batteries. In this review paper, the fundamental characteristics of several batteries are compared. In light of this, lithium-ion batteries are the most significant option for electric vehicles.*

***Key Words*: Electric Vehicle, Battery, Performance, Specific Power, Specific Energy, Life Cycles**.

1. INTRODUCTION

India's market for electric vehicles is slowly expanding. The Indian EV market environment at the moment is shown in Fig .1

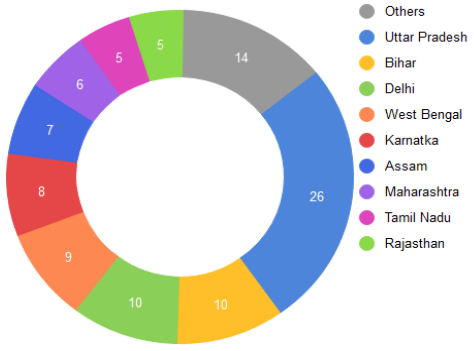


Fig -1. Regional sales of electric vehicles in India 2020 from Jan-Dec. in percentage

Research on EV technology progress, focusing mostly on battery electric vehicles, is ongoing in many parts of the world due to limited energy resources and environmental impact. Only 450 units were sold by Indian manufacturers in 2016. Through government subsidies and incentives for EV adoption, India has a significant opportunity to grow its market share. Given that a total of 995,319 EVs across all vehicle segments were sold in 2022, a significant 509% increase over the 163,458 EVs sold in 2019, a year before to the launch of COVID, and a 208% rise year over year (all-India EV sales in 2021: 322,871 units).

Main Components of EV's are:

1. **Charger**
2. **convertor**
3. **Battery**
4. **Motor**

About 50% of the cost of electric vehicles is related to the battery. Reducing the price of the battery pack is crucial to boost EV sales. So it's crucial to choose a battery pack that's both affordable and efficient.

2. TYPES OF BATTERIES:

There are different types of batteries available in market. Slection of battery type is baed on energy storage capacity, construction details , safety, cost price and efficiency.

There are mainly four types of batteries available in the market:

1.Lead acid battery
2. Nickel metal hydride battery
3.Lithium ion battery
4.Other batteries

2.1 Lead acid battery:

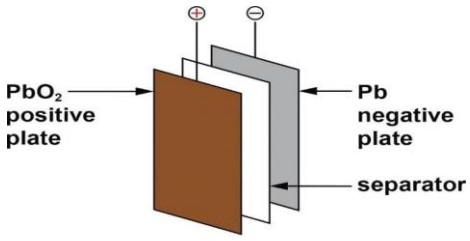
Gaston Plante, a French chemist, created the first lead acid battery in 1860. It is a battery that can be recharged. The least expensive battery option is flooded lead-acid, which was also the most popular power source in the past.

Two types of flooded lead-acid batteries can be distinguished as follows:

1. engine starter batteries
2. deep cycle batteries.

When an engine starter operates and is charged by the car's alternator, an engine starter battery produces a brief but

powerful surge current. EVs like "forklifts or golf carts" employ "deep cycle batteries" which are made to be periodically deeply discharged. It has a positive plate made of brown lead dioxide and a negative plate made of lead metal, both of which are submerged in an electrolyte of diluted sulfuric acid. A lead-acid battery stores electrical energy that can be transformed from chemical energy to electrical energy.



$$Pb + PbO_2 + 2H_2SO_4 \rightleftharpoons 2PbSO_4 + 2H_2O$$

Fig-2: Chemistry and main lead-acid battery components.

The lead-acid battery has the following reversible reactions:

Positive electrode reaction:
$PbSO4 + 2H2O \leftrightarrow PbO2 + 3H^+ + HSO4^- + 2e^-$
Negative electrode reaction:
$H^+ + PbSO4 + 2e^- \leftrightarrow Pb + HSO4^-$
Net reaction:
$2PbSO4 + 2H2O \leftrightarrow PbO2 + Pb + 2H^+ + 2HSO4^-$

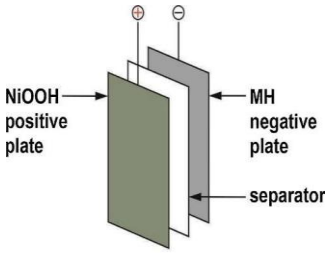
Advanatages:
1. High availability
2. Low cost
3. High reliability

Disadvantages:
1. Low specific energy
2. Low energy density
3. Maintainance cost is high
4. Less life of service

Lead acid batteries store less energy per unit of mass or volume than lithium ion batteries, which is why they are not frequently employed in electric vehicles. They typically ride in slow electric vehicles.

2.2 Nickel Metal Hydride batteries

In nickel metal hydride batteries nickel hydroxide is present at positive electrode, various materials as a negative electrodes and a potassium hydroxide solution as the electrolyte.



$$MH + NiOOH \rightleftharpoons M + Ni(OH)_2$$

Fig-3: A nickel-metal hydride battery's chemistry and main parts.

Due to different materials used as negative eletrodes Nickel batteries are classified as:
1) Nickel-iron (Ni-Fe) batteries
2) Nickel-cadmium(Ni-Cd) batteries
3) Nickel-zinc (Ni-Zn) batteries
4) Ni-MH batteries
5) Nickel-hydrogen (Ni-H2) batteries

Table -1. Advantages & Disadvantages of Nickel Batteries.

Material	Advantages	Disadvantages
Ni-Fe	Better for traction applications	Low specific energy, power and energy density; high self-discharge, hydrogen evolution, high purchase and maintenance cost
Ni-Zn	High specific energy	High cost, short service life
Ni-Cd	High specific energy	High cost cadmium toxicity, recycling issues
Ni-MH	High specific energy, safety, long service life	High cost, high self-discharge, memory effect
Ni-H_2	Extreme long-life cycle and tolerance to overcharge or over-discharge without damage	Expensive, low volumetric energy density, self-discharge proportional to H_2 pressure

From above types Ni-MH batteries is popular choice for EV. Electrochemical reactions in Ni-MH battery:

$X + 2NiO(OH) + 2H_2O \leftrightarrow 2Ni(OH)_2 + X(OH)_2$
$M(H) + 2NiO(OH) \leftrightarrow M + Ni(OH)_2$
$H_2 + NiO(OH) \leftrightarrow Ni(OH)_2$

The patent encumbrance of Ni-MH batteries for heavy-duty vehicles has caused a stagnation in the usage of Ni-MH batteries in electric vehicles (EVs) in recent years.

2.3 Lithium-ion Batteries

After being manufactured for the first time in a commercial setting by the Sony Company in 1991, lithium-ion batteries dominated the market for energy storage and portable electric devices. They are lightweight, tiny, and have a lot of power storage capacity all at once. The lithium-ion battery has considerable benefits over other batteries in terms of specific energy and energy density.

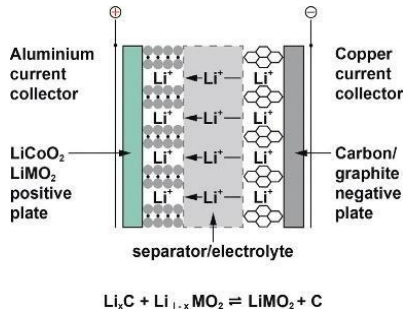


Fig-4: Chemistry and principal components of a Li-ion battery

Different materials are used in positive electrodes, accordingly lithium ion batteries include:

1. Lithium cobalt oxide ($LiCoO_2$) batteries
2. Lithium manganese oxide ($LiMn_2O_4$) batteries
3. Lithium iron phosphate ($LiFePO_4$) batteries
4. Lithium nickel-manganese-cobalt oxide ($LiNiMnCoO_2$ or NMC) batteries
5. Lithium nickel-aluminum-cobalt oxide ($LiNiCoAlO_2$ or NCA) batteries
6. Lithium titanate ($Li_4Ti_5O_{12}$) batteries

As mentioned above, LiFePO4 batteries are frequently used in electric vehicles because they offer superior chemical and thermal stability at a reasonable price.

Advantages of lithium ion batteries:

1. High energy efficiency
2. Life cycle is long
3. Power density is better

Table-2. Advantages & Disadvantages of Lithium ion Batteries

Material	Advantages	Disadvantages
$LiCoO_2$	In common use, high power density, high energy density	Low self-discharge, low safety, high cost
$LiMn_2O_4$	High power density, very good thermal stability	Moderate cycle life, lower energy
$LiFePO_4$	Very good thermal stability and cycle life, good power capability no memory effect, lighter and smaller	Low energy density
$LiNiMnCoO_2$	High power density, high energy density, high energy efficiency, good cycle life	Structural/chemical instabilities during repeated cycling

2.4 Other types of energy storage systems

1. Sodium Nickel Chloride batteries
2. Metal–air batteries
3. Sodium-beta batteries
4. Fuel cells (FCs)
5. Ultracapacitors

From above **Sodium Nickel Chloride** battery is commonly used.

2.4.1 Sodium nickel chloride battery:

Batteries made on sodium nickel chloride are known as Zebra batteries. The "Zero Emission Battery Research Activity" (ZEBRA) project is where the name "Zebra" originated. A molten salt electrolyte found in Zebra batteries can only remain liquid at temperatures between 300 and 350 C.

The normal cell reactions are as follows:
Positive electrode: $NiCl2+2Na^{+}+2e- \rightarrow Ni+2NaCl$
Negative electrode: $Na \rightarrow Na^{+}+e-$
The Net reaction is $NiCl2+2Na \rightarrow 2NaCl+Ni$

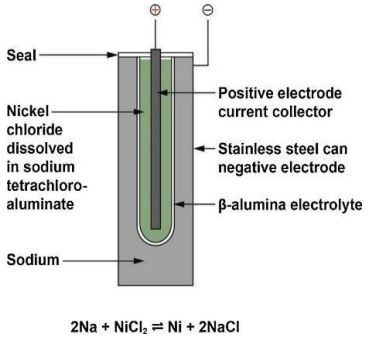


Fig-5: Chemistry and main components of a sodium-nickel chloride battery.

Advantages:

1. High energy density
2. Low corrosion
3. High safety
4. Long life-cycle
5. Lowest price

Disadvatages:

1. Low specific power
2. Self-discharge problem

Other applications for these batteries include submarines, military hardware, telecommunications systems, and power storage.

3.Results:

Table-3: Various Parameters for Batteries

Cathode Material	Specific Energy (Wh/kg)	Cycle	Optimal Working Temp (°C)	Efficiency (%)
Lead acid	30–50	500–1000	-20–60	70–90
Ni-Fe	30–55	1200–4000	-10–45	75
Ni-Zn	60–65	100–300	-10–50	76
Ni-Cd	40–50	2000–3000	-40–60	60–90
Ni-MH	50–70	500–3000	-40–50	50–80
Ni-H_2	60–70	6000-40000	-20–60	80–90
$LiCoO_2$	150–190	500–1000	150	80–90
$LiMn_2O_4$	100–135	500–1000	250	85
$LiFePO_4$	90–120	1000–2000	270	90
$LiNiMnCoO_2$	140–180	1000–2000	210	90–95

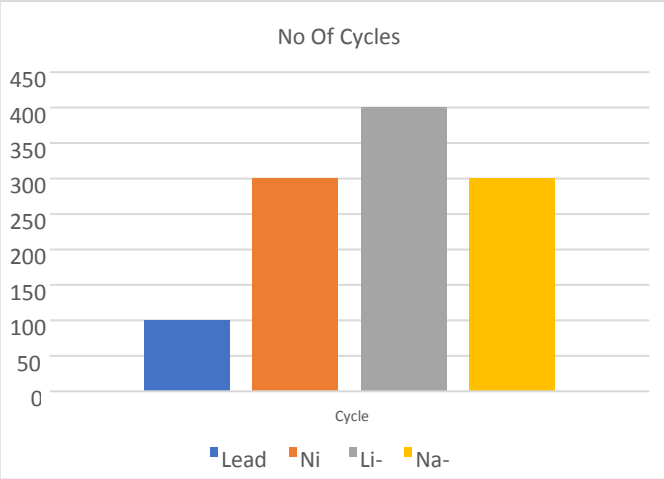


Fig- 6: No of Cycles

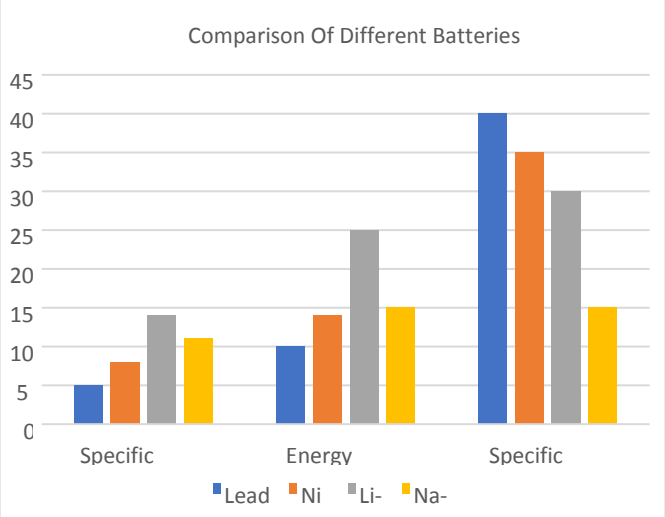


Fig- 7: Camparision Of Different Batteries

4. CONCLUSIONS

The batteries used in electric vehicles are illustrated in this article. Choosing the right battery is a crucial factor. Nowadays, batteries with high specific energy and high energy density, including Zebra batteries and lithium-ion batteries, are used as the power source of EVs instead of the conventional lead acid batteries. Lithium ion batteries have the highest specific energy (about 150 Wh/kg), energy density (250 Wh/L), and number of lifecycles (4000). Less advantageous for electric vehicles are lead acid batteries with 1000 life cycles and 100 Wh/L energy density and Ni-MH hydride batteries with 3000 cycles and 140 Wh/L energy density.

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