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Comparison of Different Batteries for Electric Vehicles

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ABSTRACT:

People began looking for ecologically friendly vehicles as a result of public awareness of the finite supply of fuel the availability of energy worldwide and the emission of greenhouse gases by internal combustion vehicles. Electric vehicles with battery power play a big part in the automobile business today. Electric vehicles are built using a variety of battery types. However, choosing the ideal sort of battery is difficult, so we must consider a few factors, including energy storage effectiveness, constructive qualities, cost, safety, and utilisation life. Different types of batteries are discussed in this study, including Lead-acid, Nickel Cadmium (Ni-Cd), Nickel Metal Hydride batteries (Ni-MH), Sodium Nickel chloride (Na-Nicl2) and Lithium Ion (Li-ion)-Cobalt, Manganese, Phosphate.

KEYWORDS: Electric Vehicles, Lead-acid, Nickel Cadmium, Nickel Metal Hydride, Sodium Nickel Chloride, Lithium Ion-Cobalt, Manganese, Phosphate batteries.

1. INTRODUCTION:

People began searching for alternatives to internal combustion engines as a result of public awareness of the finite supply of fuel energy around the globe and the release of greenhouse gases by those vehicles. The use of ecologically friendly automobiles that different rechargeable energy sources. Considering that one of the ideas of deploying electric vehicles, and renewable energy sources on the scene was to power up the car. Even though electricity and the motors in the vehicles will be powered by renewable energy, The idea of an electric car was not previously known to the globe. Till 1859, that is. The identical year, the rechargeable Gaston Plante initially came up with the moniker "lead-acid battery" for the battery. Batteries are crucial to the development of electric vehicles since they are required to havea transportable gadget that collects power to run the motor's power supply. Engines in automobiles over time. the percentages of electric vehicles and internal combustion engines had to refuel the energy. In contrast to refuelling, charging takes longer in the batteries of electric vehicles have longer ranges. The lengthy battery recharging process could be rather exasperating for those who use electric automobiles.

among the 4800 automobiles sold in the US in 1900 38%, 22%, and 40% of all vehicles were steam-powered. Electric vehicle demand is very high at that time. Frantically, the appeal of electric automobiles faded, and Only 30 years later, the desire for it was all but gone. In 1930, the need for electric cars was nearly replaced by the demand for automobiles with internal combustion engines.

However, following the 1970s declaration of oil scarcity and environmental issues and knowledge of the air quality in the 1980s, people are beginning to renew their enthusiasm for electric cars. As more individuals became concerned aboutthe environment, the development of electric automobiles increased. One of the numerous nations

In the globe that strongly encourages its nations to use electric automobiles. The government of Norway encourages the use of electric vehicles by modifying policies like waiving tolls on roads and limiting lanes for accessing charging station infrastructure along with other transportation options, public transportation. Utilizing electric vehicles can undoubtedly result in various benefits. Advantages for the society of humankind. perhaps the most evident advantages of utilizing electric vehicles include the reduction in the release of greenhouse gases. Powered by electricity, electric mostly by electric motors, which don't need combustion to operate. Automobiles are like vehicles with internal combustion engines. The greenhouse gas emissions from electric vehicles are nil because they don't burn anything.

2.ADVANTAGES AND DISADVANTAGES USING ELECTRIC VEHICLES:

However, using electric vehicles has disadvantages as well as advantages over those powered by internal combustion engines. The long wait times for charging electric vehicles are one of its drawbacks. Replenish the batteries in electric automobiles. Using electricity users were obliged to charge their automobiles precisely just similar to how users ofinternal combustion engines had to refuel the energy. In contrast to refuelling, charging takes longer in the batteries of electric vehicles have longer ranges. The lengthy battery recharging process could be rather exasperating for those who use electric automobiles.

3. EXPLANATION:

3.1. BATTERY FOR TRACTION:

One of the key parts of the electric was the traction battery. mostly automobiles, locomotives, and industrial traction are used by trucks and mechanical handling equipment. Power sources like batteries. Additionally, you might make use of this electric car battery as a rechargeable traction battery(EVB). Unlike supplementary batteries, traction batteries support all-electric vehicles rather than just the energy required for automobiles' engines to start. a lead-acid battery, a nickel-metal hydride (Ni-MH) battery, or a nickel-cadmium battery lithium and nickel-metal hydride batteries (NiMH) are illustrations of large traction batteries.

3.2. LEAD-ACID:

The lead-acid battery, invented by Gaston Planté in 1859, is the first rechargeable traction battery in history. an acid-based battery Camille Alphonse modified the lead-acid battery when he created the first type of rechargeable battery ever used commercially, particularly in the automobile sector. Lead-acid batteries have developed since they were first introduced by Faure in 1881, both in terms of their effectiveness and capacity. Environmentally friendly processes were used in the production of lead-acid batteries. Faure, Camille Alphonse. Lead-acid battery improvement also is simplified. Despite being 160 years old in 2019, lead-acid batteries continue to have a substantial impact. Given its low cost in the automotive sector.

3.3. NICKEL METAL HYDRIDE BATTERY (NIMH):

A more advanced version of the Nickel Cadmium battery is the Nickel Metal Hydride battery. since it uses hydrogen added to metallic alloys at the negative electrode rather than cadmium. To stop the Nickel-Metal Hydride battery which is continuously sealed to prevent hydrogen from leaking. The energy density of nickel metal hydride batteries has greatly increased, and they are currently replacing nickel-cadmium batteries in the production of electric vehicles. The nickel-metal hydride battery was not widely used in the 1990s because newer storage technologies appeared so fast after its creation.

3.4. NICKEL CADMIUM BATTERY (NICD):

Society has been using nickel-cadmium batteries extensively, and they are meant to replace lead-acid batteries, particularly in European-made cars. In the 1980s and 1990s, nickel-cadmium batteries were created for use in electric vehicles. Because of its long battery cycle life, nickel-cadmium batteries are well-known. Unfortunately, the Nickel Cadmium battery industry did not grow due to its relatively small variety and high selling price.

3.5.SODIUM NICKEL CHLORIDE ($Na\text{-}Nicl_2$):

Batteries made of sodium-nickel chloride, often known as ZEBRA batteries, are high-temperature devices that operate normally between 270°C and 350°C. The sodium and nickel chloride electrodes in its cell development are a beta-alumina electrolyte, which can conduct sodium ions but not electrons, and act as a barrier between them.Creator demonstrates how a sodium-nickel chloride battery operates, performs, is produced, and is used (Sudworth, 2001). These batteries have a high energy density, are small and light, react quickly, and can withstand a full discharge. Its drawbacks include self-discharge and a hefty price tag. Recently, the concept has primarily been used in submarines and electric vehicles (Osaka & Datta, 2000). Despite being widely developed and permitted for use in submarines and electric cars, this electrochemistry remains in its initial stages.

3.6. LITHIUM ION(Li-Ion):

The world was first introduced to rechargeable lithium-ion batteries in the 1990s, which had a sizable weight advantage over traditional battery systems. One of the most exceptional qualities in the modern electrochemical sector is the lithium-ion battery. Currently, it is among the most popular and commonly used batteries in electric cars. Lithium-ion batteries are competitive because they are less heavy than other battery systems. Due to its high specific energy, which is around three times greater than a lead-acid battery, the lithium-ion battery has a significantly greater travel distance.. The lithium-ion battery has clear advantages in the automobile industry because of itslong cycle life, lot of energy, and excellent efficiency. Most likely, lithium-ion batteries will have a greater impact.

4. ELECTROCHEMISTRY:

Many of the modern developments have been made possible by batteries with electrochemical energy storage capabilities. Batteries are commonly employed in a wide range of machines and devices, but it is the intricate chemistry that takes place inside the battery cells that makes modern comforts possible. All of the parts that make up a battery are contained in the positive and negative terminals, sometimes referred to as cathode and anode, electrolyte, and container. The electrolyte is added to allow the ions to flow while separating the anode and cathode. An electrochemical reaction takes place between the terminals of a battery when a load or power source is inserted, converting chemical energy to electrical energy. In this process, the anode oxidizes, giving or taking electrons from the terminal. The cathode undergoes reduction during this time, where the electrode interacts with the ions and absorbs the electrons supplied by the anode. Simply said, the cathode uses the electrons that the anode releases and absorbs them.

For use in electric cars, a variety of rechargeable battery types are currently accessible. The batteries are enhanced and changed over time to have better quality and chemical characteristics. The evolution of batteries can be categorized into lead-acid batteries, nickel-metal hydride batteries, sodium-nickel chloride batteries, and lithium-ion batteries. Lithium-ion batteries currently dominate the major commercial market. Therefore, a brief description of the electrochemistry of all rechargeable batteries used in electric vehicles will be provided, along with a discussion of current advancements in the material selection for lithium-ion battery electrodes.

The layers of lead alloy plates that cover the individual cells that make up a lead-acid battery are immersed in an electrolyte. Lead dioxide-containing plates serve as the positive electrodes in each cell, while lead-containing plates serve as the negative electrodes. Both plates are submerged in an electrolyte that contains about 65% water and 35% sulfuric acid and are separated by an insulated separator.

For the purpose of converting energy, massive chemical processes occur when a lead acid battery is charged and discharged.

The molecules of diluted sulfuric acid disintegrate, forming positive hydrogen ions (2H+) and negative sulphate ions (SO4). The positive hydrogen ions (2H+) migrated toward the negative electrode if a DC supply was supplied to the terminals. Additionally, the electrode that is connected to the positive electrode attracts the negative sulphate ions (SO4). At the cathode, the hydrogen ions are given two electrons to create a hydrogen atom. Lead (Pb) and sulfuric acid are the products of this atom's reaction with lead sulphate (PbSO4) (H2SO4).

In nickel-metal hydride batteries with a solid hydride cycle, hydrogen is kept as an active component. The negative electrode of the nickel-metal hydride battery acts as a container for storing hydrogen that releases hydrogen during charging and discharging, enabling the electrochemical reaction to take place. This electrode is made of a metal hydride, which is usually a lanthanum-rich rare earth alloy. A battery cell's positive electrode is comprised of the nickel hydroxide compound Ni (OH). Oxidation and reduction take place at both electrodes through an electrolyte that includes 30% by weight of alkaline potassium hydroxide (KOH) in water.

In a charging state. Nickel hydroxide Ni(OH)2 electrode underwent oxidation. Nickel oxyhydroxide (NiOOH) and water are created when the hydroxyl ion combines with the nickel hydroxide, Ni(OH)2. The hydrogen-absorbing alloy-representing MH electrode, on the other hand, is diminished. Hydrogen is obtained from water and again combines with the metal to create MH in the cathode. Ni(OH)2 acted as the positive electrode in an electrochemical reaction with nickel oxyhydroxide to promote reversibility (NiOOH). Therefore, the direction of the nickel-metal hydride battery's charging and the discharging stream is reversed.

The negative electrode of a sodium-nickel chloride battery is formed of liquid sodium, while the positive electrode is composed of a mixture of nickel (II) chloride (NiCl2) and iron (II) chloride (FeCl2). As an electrolyte, Na-alumina (Na2Al11O17), a ceramic solid metal, is used to divide the two electrodes. It prevents direct chemical interactions between the elements of the electrode while allowing sodium ions to pass between the electrodes. In order to speed up the transit of sodium ions to the positive electrode, a second electrolyte called sodium tetra chloro-aluminate (NaAlCl4) is used. The diagram in shows the structure of a sodium-nickel chloride battery cell.(Fig1)

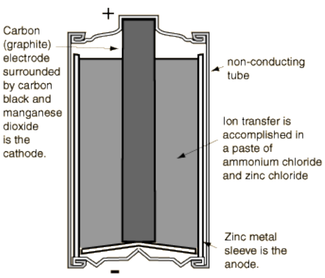

Fig1: Battery Cell

Aluminium, iron, nickel, and table salt are combined by the positive electrode to create the metal chloride phase in the discharged state. These metals are oxidized during the initial charge, which causes the salt to disintegrate into sodium and chloride ions. When chloride ions interact and combine with oxidized metals, metal chlorides are produced. It is possible to halt the chemical reaction that causes a cell to discharge.

In order for lithium ions to react with both the negative and positive electrodes in lithium-ion batteries,the energy storage system transports charges. Sony was the first company to produce and market lithium-ion batteries in 1991. Armand is credited for creating the concept of reversibility in the transfer of lithium-ion between electrodes in batteries, using various intercalated materials for two electrodes. Lithium ions can go back and forth between the two electrodes thanks to it. The reversibility of the NaFeO2 crystal structure was discovered by the Goodenough laboratory during the deintercalation of lithium ions at relatively high potentials. Later, it was discovered that metals with a nickel and cobalt mixture, such as magnesium, aluminium, iron, etc., had a comparable ability, and lithium cobalt oxide (LiCoO2) was used as the active positive material for Sony's lithium-ion battery.

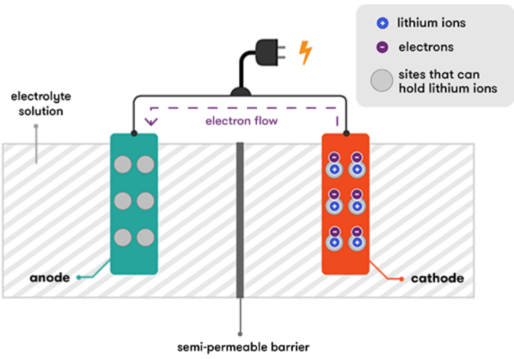

Fig 2: Lithium-Ion Cell

4.1.CATHODE:

The positive or oxidizing electrode known as the cathode is decreased during the electrochemical process after receiving electrons from the external circuit. The electrolyte is the fluid that acts as a conduit for ions moving between a cell's cathode and anode.

4.2. ANODE:

The anode is the negative or reducing electrode that undergoes electrochemical reactions and delivers electrons to the external circuit while oxidizing. The positive or oxidizing electrode known as the cathode is decreased during the electrochemical process after receiving electrons from the external circuit.

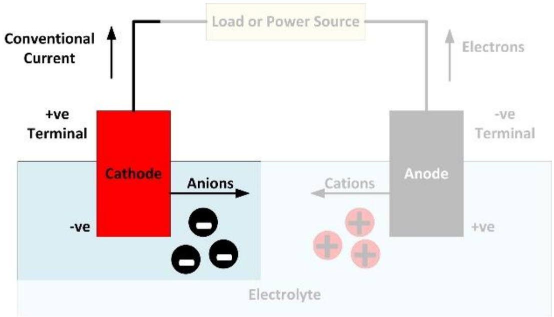

Fig3:Cathode and Anode.

5. BATTERIES PARAMETER:

The most important part of the electric car is its traction battery system. Without the primary battery, the electric motor can only operate in a limited way. In order to increase the efficiency for each parameter, EV battery manufacturers recently continued to develop new types of batteries for EVs in addition to inventing and improving the current batteries.

5.1.SPECIFIC ENERGY DENSITY:

Energy density, also known as volumetric energy density, reflects volume in litres (Wh/l), whereas specific energy, or gravimetric energy density, describes battery capacity in weight (Wh/kg). The capacity to provide high current loads can be disregarded in products that need to run for a long time at a moderate load.

5.2.INTERNAL RESISTANCE:

The opposition to current flow inside a battery is known as its internal resistance or IR. Ionic resistance and electrical resistance are the two fundamental factors that affect a battery's internal resistance.

5.3. CYCLE LIFE:

The number of charges and discharge cycles a battery may go through before losing its effectiveness is known as cycle life. The depth of discharge has a considerable impact on the cycle life of Li-ion batteries. The percentage of a battery's storage capacity that is used depends on the depth of discharge.

5.4.FAST-CHARGE TIME:

The term "fast charging" is widely used to promote chargers and gadgets that can charge more quickly than the current charging standard (5 Watts). There is no industry-standard terminology for very fast charging speeds, despite the fact that several technologies make them possible.

5.5.OVER CHARGE TOLERANCE:

More and more energy enters the cell if neither the charger nor the protection circuit stops the charging process. As a result, overcharging occurs as the voltage in the cell increases. On the one hand, the battery will suffer from this and have a shorter lifespan.

5.6.SELF DISCHARGE:

Technology for self-charging batteries. A battery cell that can generate electricity from air or skin surface humidity is being developed with the goal of competing in the $1 trillion worldwide Internet of Things (IOT) device battery market.

5.7.CELL VOLTAGE:

The typical voltage that a cell produces when charged is known as nominal cell voltage. The chemical reaction that powers a battery determines its nominal voltage. The output of a lead-acid automobile battery is 12V. 3V is the output of a lithium coin cell battery.

5.8.CHARGE CUT-OFF VOLTAGE:

The cut-off voltage in electronics refers to the point at which a battery is deemed entirely depleted and past which additional discharge may be hazardous. When the cut-off voltage is reached, some electronics, such as cell phones, will automatically switch off.

5.9.DISCHARGE CUT-OFF VOLTAGE:

The cut-off voltage in electronics refers to the point at which a battery is deemed entirely depleted and past which additional discharge may be hazardous. When the cut-off voltage is reached, some electronics, such as cell phones, will automatically switch off.

5.10.PEAK LOAD CURRENT:

The largest amount of current that output is capable of providing for brief periods of time is known as the peak current. When an electrical device or power source is turned on for the first time, a large initial current known as the peak current flows into the load, starting at zero and increasing until it reaches a peak value.

5.11.CHARGE TEMPERATURE:

To maximize performance and range during discharge cycles, keep the battery temperature between 20 and 30 °C. During charging, keep the battery's temperature between 15 and 25 °C. If possible, cool additional powertrain parts to enable derating-free operation.

5.12.DISCHARGE TEMPERATURE:

Your battery losing voltage or energy is known as discharging or draining. It's crucial to realize that if a battery isn't being directly charged, it is constantly discharging. Due to the accelerated chemical reactions occurring inside the battery, the self-discharge rate rises as the temperature does.

5.13. MAINTENANCE REQUIRED:

Battery maintenance mode denotes a state in which the battery charger system is connected to input power and the battery charger may deliver current to the battery to counteract or compensate for self-discharge of the battery. Ascertain that the battery top is clean, dry, and free of dirt and grime. A contaminated battery can discharge across the grime on the battery casing. Examine the terminals, screws, clamps, and cables for any signs of breakage, damage, or loose connections. These should be clean, tight, and corrosion-free.

5.14.SAFETY REQUIREMENTS:

Batteries have the potential to be harmful if they are misused or improperly designed. Because of these risks, cell manufacturers incorporate safety features into their products. Similar to battery manufacturers, pack manufacturers add safety mechanisms into the pack designs to protect the battery from abusive use and out-of-tolerance operating circumstances. It has frequently been mentioned how challenging it is to make a battery failsafe because fools may be so crafty. The user controls the battery's destiny once it leaves the factory. Battery products typically come with "Instructions For Use," which warn the end user of potential risks from improper battery use. Unfortunately, twisted fools will always find these guidelines to be a challenge.

Table1:Comparrsion table of different types of batteries

Specifications	Lead Acid	NiCd	NiMH	Li-ion Cobalt	Li-ion Manganese	Li-ion Phosphate
Specific energy density (Wh/kg)	30–50	45–80	60–120	150–190	100–135	90–120
Internal resistance[1] (mΩ)	<100 12V pack	100–200 6V pack	200–300 6V pack	150–300 7.2V	25–75[2] per cell	25–50[2] per cell
Cycle life[4] (80% discharge)	200–300	1000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Fast-charge time	8–16h	1h typical	2–4h	2–4h	1h or less	1h or less
Overcharge tolerance	High	Moderate	Low	Low. Cannot tolerate trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<10%[6]		
Cell voltage (nominal)	2V	1.2V[7]	1.2V[7]	3.6V[8]	3.8V[8]	3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75	1.00		2.50 – 3.00		2.80
Peak load current Best result	5C[9] 0.2C	20C 1C	5C 0.5C	>3C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C	0 to 45°C		0 to 45°C[10]		
Discharge temperature	–20 to 50°C	–20 to 65°C		–20 to 60°C		
Maintenance requirement	3–6 months[11] (topping chg.)	30–60 days (discharge)	60–90 days (discharge)	Not required		
Safety requirements	Thermally stable	Thermally stable, fuse protection common		Protection circuit mandatory[12]		
In use since	Late 1800s	1950	1990	1991	1996	1999

6.CONCLUSION:

From an energy consumption perspective, Na-NiCl2 batteries have proven to be the best option (12.6 kWh/100 km). Other significant benefits include their low cost, longer life span, or excellent performance within typical limits in severe situations. These batteries one drawback is the higher operating temperature, which, if the vehicle is not driven, is causing the battery electrolyte to harden. Used. Because of this, a single external system that ensures the battery's functionality is required. The temperature is within acceptable limits.

Studies have shown that Li-S batteries have the highest energy consumption (17.2 kWh/100 km), which is supported by the data. However, compared to other battery technologies, they may be one of the most advantageous due to their lightweight, enhanced energy storage capacity, and low cost.best options for systems with a large amount of energy storage.Despite having moderate energy usage (15.7 kWh/100 km), Ni-MH batteries are stillineffective, having a higher energy density and power, being weighty, and being out of date technology.

Li-Ion batteries currently make up the largest market category for electric car equipment. Li-Ion batteries are the best option in this area because to their low weight, large energy storage capability, moderate energy consumption (14.7 kWh/100 km), constant cost price drop, advanced production technology, increased cycle life, and moderate energy consumption. Their downside is that they operate at high temperatures, which may have an adverse impact on their life cycles and energetic capabilities. All of these pose dangers to the vehicle's safe operation.

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