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REVIEW ARTICLE

Battery Technologies Comparison for Electric Vehicles

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Abstract

Objectives: The purpose of this study is to provide an overview of the recent advancements in lithium ion (Li-ion), lead acid, and nickel metal hydride (NiMH) batteries utilized in electric vehicles (EVs). **Methods:** The study considered in improving the batteries' performance concerning energy and power densities, safety, and cost. Various methods reported have been analysed and compared. **Findings:** For Li-ion batteries, researchers have developed new cathode and anode materials such as silicon, lithium-sulfur, and lithium-air. Solid-state electrolytes have also been explored to improve safety and longevity. In contrast, research on lead acid batteries has focused on enhancing their cycling performance, reducing their size and weight, and increasing efficiency. Finally, for NiMH batteries, researchers have developed nickel-cobalt-manganese cathodes to enhance energy and power densities. Recent research has been successful in improving battery performance for all three types. The use of silicon anodes and lithium-sulfur cathodes has resulted in significant improvements in energy density for Li-ion batteries. Additionally, carbon additives and new separator materials have improved cycling performance and efficiency for lead acid batteries. The use of nickel-cobalt-manganese cathodes has led to improved energy and power densities for NiMH batteries. **Novelty:** The emphasizes for the development of new materials and technologies that address the limitations of existing battery technologies, thereby making EVs more practical and competitive with gas-powered vehicles. We have supported this review with a simple simulation of the batteries mentioned above, to explain their operation.

Keywords: Batteries Comparison; Lead Acid; Ni Mh; Li-Ion; DC Motor

1 Introduction

The demand for electric vehicles (EVs) has significantly increased over the years due to their eco-friendliness and economic benefits. The success of EVs relies heavily on the performance of their batteries. Lithium-ion (Li-ion), lead-acid, and nickel-metal hydride (NiMH) batteries are commonly used in EVs, and the advancements in these batteries have been the focus of recent research. Li-ion batteries have gained popularity in the EV industry due to their high energy density and long cycle life. The research has been focused on developing new cathode and anode materials to improve the performance of Li-ion batteries. For instance, the development of SiOx coated silicon anodes for Li-ion batteries has been discussed in reference[1]. References[2–4] focus on the development of high-performance cathode materials, while reference[5] discusses a synthesis of lithium iron phosphate with excellent rate capability. Lead-acid batteries are a popular choice for EVs due to their low cost and reliability. Recent research has been focused on enhancing the performance of these batteries by using graphene oxide membranes, as discussed in reference[6]. Furthermore, a novel structural design for weight reduction has been proposed in reference[7]. NiMH batteries have also been used in EVs, but their performance lags behind Li-ion batteries. The research has been concentrated on understanding the degradation mechanism of NiMH batteries at high temperatures, as discussed in reference[8] The advancements made in Li-ion, lead-acid, and NiMH batteries have made them more promising for the future of EVs. Reference[9] discusses the improved electrochemical performance of carbon-coated LiFePO4/C cathode materials synthesized through a microwave-assisted hydrothermal method for Li-ion batteries. Reference[7] presents a comprehensive review of the state-of-the-art Li-ion battery technology for EVs. Reference[10] describes the advancements in Li-ion battery recycling and their role in creating a circular economy. Reference[11] presents a comparative study of the environmental and economic impacts of different battery technologies used in EVs. In reference[12] a cost-effective and sustainable approach to the production of Li-ion batteries is discussed. In addition to the afore mentioned batteries, there has been significant research on other emerging battery technologies, such as sodium-ion and solid-state batteries, for use in EVs. References[13–15] discuss the advancements in sodium-ion batteries for EVs. References[16] [17] present the development of solid-state batteries for use in EVs. Furthermore, references[18–20] describe the use of artificial intelligence and machine learning techniques in battery management systems for EVs. Reference presents[21] a review of the current status and future prospects of EVs and their batteries. Reference[22] discusses the use of blockchain technology to enable sustainable supply chain management for Li-ion batteries. References[23,24] highlight the role of battery thermal management in improving the performance and longevity of EV batteries. Reference[25] presents the development of an efficient and fast charging method for Li-ion batteries. Reference[26] discusses the development of a smart charging infrastructure for EVs. References[27,28] focus on the use of Li-ion batteries in commercial vehicles, specifically electric buses. Reference[29] presents a study on the optimization of the power train and battery of electric motorcycles.

Batteries are a critical component of electric vehicles (EVs). Unlike traditional gas-powered cars, EVs rely on batteries to store and deliver energy to the electric motor, which powers the vehicle. As such, the performance, range, and cost of EVs are heavily influenced by the capabilities and characteristics of their batteries. Improvements in battery technology have led to significant advancements in EV performance and range, making them more viable alternatives to gas-powered cars. However, battery technology is still evolving, and there is ongoing research and development to improve battery efficiency, lifespan, and cost.

Overall, the importance of batteries for EVs cannot be overstated. They are the key to unlocking the environmental and economic benefits of EVs and are a major driver of innovation and investment in the automotive industry. One of the key benefits of EVs is their potential to reduce greenhouse gas emissions and air pollution, but this depends on the source of the electricity used to charge the batteries. Additionally, the use of batteries can reduce dependence on fossil fuels and increase energy security.

2 Methodology

EV batteries are different from Starter, Light, Ignition(SLI) batteries because they are designed to provide power for extended periods of time. These applications use deep cycle batteries instead of SLI batteries. Batteries for electric vehicles are characterized by relatively high power-to-weight ratio, specific energy**,** and energy density. Smaller**,** lighter batteries reduce vehicle weight and improve performance. There are two main types of accumulators: primary and secondary. Primaries have the disadvantage of having a chemical reaction within the battery.

These batteries are intended for electronic devices and other consumer products. Conversely, secondary accumulators have a reversible chemical reaction can therefore be recharged, they are more suitable for industrial use. We will therefore compare the different secondary accumulators.

For the simulation , we fed a direct current motor with one type of accumulator at a time, and we recorded the various simulation results.

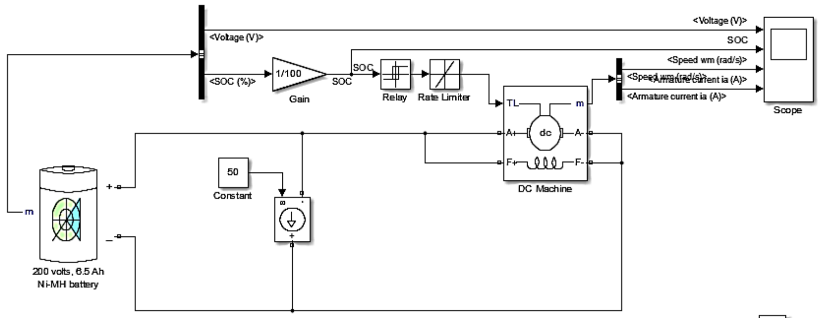

Fig 1. General scheme for the system simulation

2.1 Lead Acid battery

A lead-acid battery consists of plates, a separator, an electrolyte, and a hard plastic and hard rubber case. Batteries have two types of plates, positive and negative. The electrolyte is water and sulfuric acid. The charging of this type of battery is highly dependent on the active material (the amount of electrolyte) and plate size.

2.1.1 Operating

Upon discharge, both the positive and negative plates become lead (II) sulfate ($PbSO_4$), and the electrolyte loses much of the dissolved sulfuric acid and becomes mostly water. The discharge process is driven by a strong energy loss when the 2H+ (aq) (hydrated protons)of the acid react with the oxygen (O_2 -ions) of lead dioxide (PbO_2 = to form strong O–H bonds in H2O (per 18g of water-880kJ))[30].

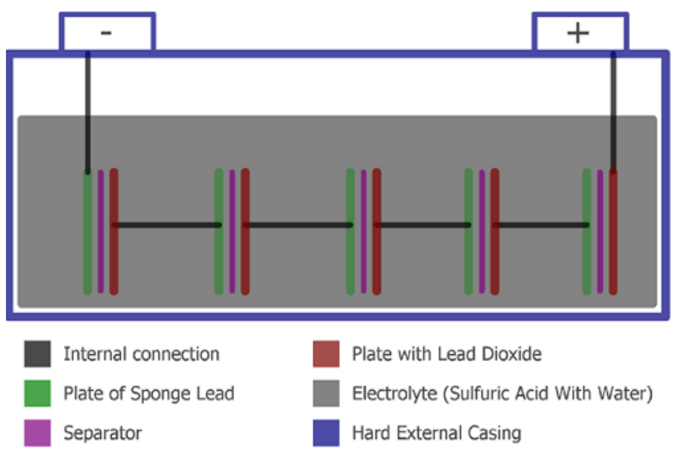

Fig 2. Lead acid battery components

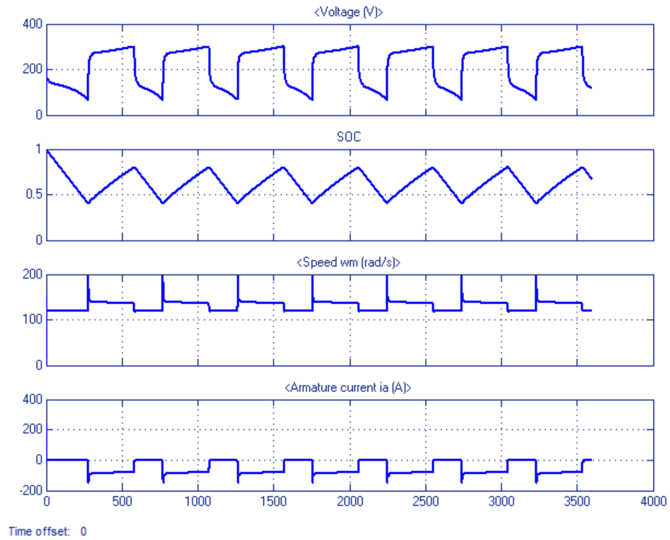

Fig 3. Voltage Battery , State of charge of the battery , speed of the motor and armature current of the motor (Lead Acid Battery)

2.2 Nickel-metal hydride battery (NiMH)

Nickel-metal hydride batteries**,** abbreviated as NiMH or Ni-MH, are a type of rechargeable battery. The chemistry at the positive electrode is similar to that of nickel-cadmium (NiCd) cells, both using nickel hydroxide (NiOOH). However, the negative electrode uses a hydrogen storage alloy instead of cadmium. A NiMH battery can have two to three times the capacity of a NiCd battery of the same size, and its energy density can approach that of a lithium-ion battery.

2.2.1 Operating

When over charge data low rate, the oxygen generated at the positive electrode passes through these parator and recombines at the negative electrode surface. Suppresses the generation of hydrogen and converts charging energy into heat. This process makes the NiMH cell hermetic and maintenance-free during normal operation.

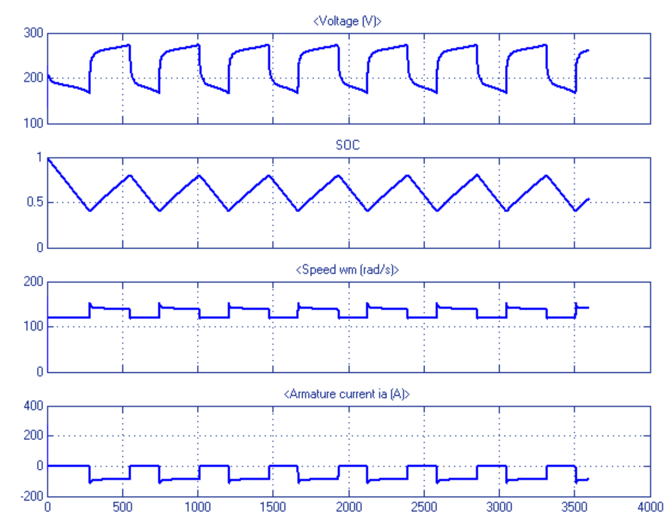

Fig 4. Voltage Battery , State of charge of the battery , speed of the motor and armature current of the motor (NiMhbattery)

2.3 Lithium-ion battery (Li-ion)

It has no memory effect and a low self-charge. Although it does not require maintenance, its service life is low. Paradoxically, it has a correct life cycle number. This means that this model wear seven if it is not used (aging, wear, corrosion, etc.). Its main advantage is its high energy density (high electrochemical potential). Lithium being a very light metal, its weight is also an advantage.

The main weakness of this model lies in its safety aspect: overheating can lead to explosion. To ensure safety, the battery must be equipped with a protective system.

2.3.1 Operating

The principle of lithium batteries is to circulate electrons by creating a potential difference between two electrodes (one negative and one positive) immersed in an ionically conductive liquid called an electrolyte. When the battery powers the device, the electrons stored in the negative electrode are released through an external circuit and reach the positive electrode. This is the discharge stage. Conversely, when charging a battery, the energy transferred from the charger causes electrons to return from the positive pole to the negative pole**.**

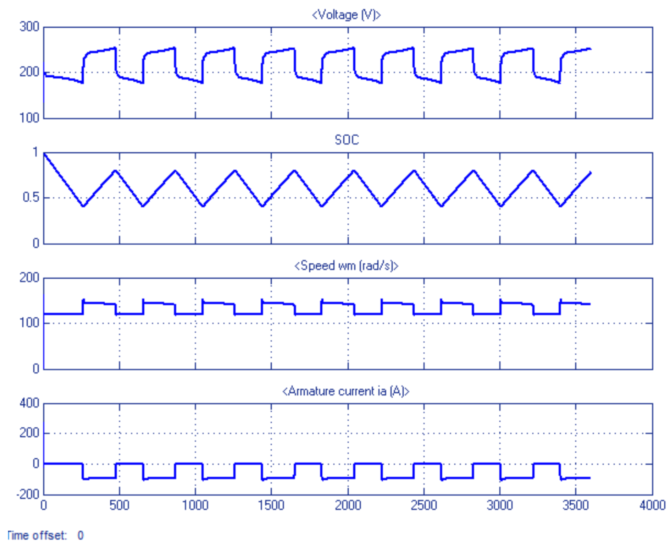

Fig 5. VoltageBattery , State of charge of the battery , speed of the motor and armature current of the motor (Li-Ion battery)

Table 1. Technology comparison of the batteries [31]

	Lead Acid	Ni Mh	Li-ion
Lifespan(year)	4-5	2-4	7
Number oflife cycle	800	1000	1000
Efficiencycharge/discharge(%)	50	66	90
Self-loading(% per month)	5	20	2
nominal voltage by element(V)	2.1	1.2	3.6
Resistance internal (ohm)	Very low	0.06	Very low
Énergie massique(Wh/kg)	30-50	60-110	90-180
Temperature in functioning(°C)	Ambient	Ambient	Ambient
Time to load (h)	8	1	2-3

In [32] it was mentioned that Recently, rechargeable lithium-ion (Li-ion) batteries are claimed as the most suitable energy storage device for EVs because of higher energy density and specific power, lighter weight, lower self-discharge rates, higher recyclability and longer cycle life compare to lead-acid, nickel– cadmium (Ni-Cd), nickel-metal hydride (Ni-MH) batteries.

In [33,34] they said that Nickel cadmium (NiCd) became the most suitable battery for the portable electronic equipment in this day. The usage of NiCd battery in the electric vehicles is developed in the 1990s. Unfortunately, the market of Nickel Cadmium battery did not expand due to its relatively low range and uncompetitive selling price.

In [35] they concluded that only 1% to 3% of total passenger cars are electric today

In [36] authors confirm that a customer willing to use an electric vehicle (EV) needs the vehicle to have shorter charging durations, lesser maintenance, and a cheaper cost of operation.

[37] This review examines the latest technological advancements in Li-ion batteries for electric vehicle applications. The authors discuss the challenges and opportunities to improve the performance, safety, and durability of batteries.

[38] This review highlights recent progress in the development of new solid electrolytes for Li-ion batteries, which may offer better safety and higher energy density than liquid electrolytes. The authors discuss technical challenges and prospects for using these materials in commercial batteries.

[39] This review examines the environmental challenges associated with the production and recycling of Li-ion batteries, as well as opportunities to improve battery sustainability by using more eco-friendly materials and cleaner production processes. The authors also discuss the socio-economic implications of transitioning to more sustainable batteries.

3 Results and Discussion

For the operation of the batteries, we can conclude, that Figure 4 shows the voltage, the state of the charge of charge, speed of the motor, and armature current of the DC motor for the lead acid battery, Figure 5 illustrate voltage, state of charge, speed of motor and its current for the Nickel metal hybride battery, and figure 6, shows all these parameters for the Lithium ion battery.

We can clearly notice that the motor speed peaks are significantly higher when powered by lid acid battery, same remark for the arùature current of the motor.

For the two others batteries, the piks are insignificant.

To compare these different batteries over the years, we will use the summary Table 1.

The lithium-ion battery has a higher mass energy than the others. Also, it has a very good charge/discharge efficiency. Its internal resistance and its percentage of self load per month is very low, this constitutes twoother weight advantages.

The references discussed highlight the importance of battery technology and cost-effectiveness in the mass adoption and wide spread use of electric vehicles (EVs). Lithium-ion (Li-ion) batteries are considered the most suitable energy storage device for EVs due to their higher energy density and specific power, lighter weight, lower self-discharge rates, higher recyclability, and longer cycle life compared to other types of batteries. However, cost-effective solutions are needed for the mass adoption of EVs, as well as improvements in charging infrastructure, battery technology, and consideration of environmental factors. As battery production costs continue to decrease and technology continues to improve, it is likely that we will see an increase in the popularity of EVs as a more sustainable mode of transportation.

4 Conclusion

In this article we have presented the latest advances in different technologies of electric batteries used for electric vehicles ,studying several recent articles in the field , we supported this review with a contribution from us, which summed up in a simulation of the three batteries involved in this study, and we concluded this :

The lead acid batteries are Inexpensive, it is often used, especially for automotive systems operating at ambient temperatures and is not sensitive to memory effect. Nevertheless, this technology is quite polluting, the number of cycles is quite low (about 500) and its energy is limited, as this summary table shows.

The Ni Mh batteries, unlike the previous ones, are not polluting. They can store more energy and are not sensitive to the memory effect. They have overall better performances, even if their self-loading are more disabling and their life span shorter in number of cycles. They hardly detect the end of load and do not support the overflow.

The Li-ion batteries have higher mass and volume energy. Also, they have a very good load/discharge efficiency, which is very important. Their internal resistance and their percentage of self load is very low.

New types of accumulators have emerged on the industrial market and are still in the process of being perfected, such as the bromine-based accumulator (with sodium-brome, zinc-brome, vanadium-brome, etc.), or the Li-air accumulator.

In recent years, there have been significant advancements in the development of Li-ion, lead acid, and NiMH batteries for use in electric vehicles. Li-ion batteries have emerged as the preferred choice due to their higher energy density, longer lifespan, and lower maintenance requirements compared to lead acid and NiMH batteries. However, lead acid and NiMH batteries continue to find use in certain applications due to their lower cost and greater availability. Looking ahead, the future of these batteries looks promising as research continues to focus on improving their performance, reducing their cost, and enhancing their sustainability. Advancements in battery chemistry, manufacturing processes, and recycling technologies are expected to bring about a new generation of batteries that offer even greater energy density, faster charging times, and longer lifespans. Overall, while Li-ion batteries have emerged as the preferred choice for electric vehicles, there is still room for improvement and innovation across all battery types. As electric vehicle adoption continues to grow, the demand for better and more efficient battery technology will only continue to increase, making continued research and development essential for the future of the industry.

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