

A Comparative Study of Lithium-Ion & Lead Acid Battery for Finding Application In Electric Car

Aniket Todankar¹, Vinit Shah², Akshay Palase³, Piyali Mondal⁴

¹Department of electrical engineering, Viva Institute of Technology, Virar, Maharashtra (India)
Email: 17405057aniket@viva-technology.org

²Department of electrical engineering, Viva Institute of Technology, Virar, Maharashtra (India)
Email: 17401073vinit@viva-technology.org

³Department of electrical engineering, Viva Institute of Technology, Virar, Maharashtra (India)
Email: 15407035akshay@viva-technology.org

⁴Department of electrical engineering, Viva Institute of Technology, Virar, Maharashtra (India)
Email: piyalimondal@viva-technology.org

Abstract— This paper investigates in details, the study of working principle, construction, basic material properties, chemical reactions, advantages disadvantages and applications of lead acid and lithium-ion batteries so that a comparative analysis can be drawn. With the help of this comparison, it will be easy to decide options between li-ion and lead acid battery for electric car. Based on the comparison made in the paper it is found that lithium ion battery is more suitable for use in electric cars than lead acid battery.

Keywords— Lead acid battery, lithium ion battery, Specific energy, Charge-discharge cycle, Electric vehicle, Energy Efficiency, Life Span

I. INTRODUCTION

Battery powered electric vehicle are replacing Internal Combustion engine vehicles due to their various advantages. Depletion of fossil fuels and the pollution done by the IC engine vehicles are the primary reasons of replacement. In this paper, a comparative study will be done on lithium ion and lead acid battery on the basis of construction, working principle, chemical composition of the batteries. A detailed study of these two batteries will be done to determine the capacity, body to weight ratio, charging-discharging cycles, efficiency, life, space it acquires and flexibility so that they can be used in electric vehicles. The study will make clear which type of battery will be suitable for electric vehicle application and up to what range. Emphasis on electric vehicles of different companies will be given to find the range of application.

II. LITHIUM-ION BATTERIES

Lithium ion batteries are one of the most advanced rechargeable batteries use in mobile power source for portable battery devices being widely used in cell phones and laptops. The newest application of it being electric and hybrid cars which requires high power, high capacity, high charging rate, long life and improved safety. [7]

1.1 CONSTRUCTION

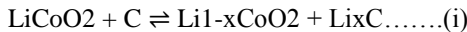
There are 3 main components of a lithium ion battery just like other batteries namely anode cathode and electrolyte solution. The positive cathode was made of lithium cobalt oxide (LiCoO₂) and has been the predominant positive material. They have high energy density and cycle life of around 500-700 deep discharge cycles. The main problem of this kind of batteries was that it releases large amounts of energy and can result in fire if it is abused. This problem had led researchers to find new material for anode and which paved the way for lithium manganese oxide, LiMn₂O₄, also known as spinel for its crystal structure but citing to its rapid capacity fading it wasn't widely used. For safety of positive electrode material it is necessary to look away from oxide materials and move to materials based on phosphates. So lithium iron phosphate was developed, cells using LiFePO₄ have reasonable life and excellent cycling properties if they are operated at moderate temperatures. For negative anode graphite is used as the negative material Conventional graphite negatives operate at a voltage only about 150 mV higher than that of lithium

metal. The electrolyte used in lithium-ion cells is normally lithium hexa fluorophosphate (LiPF₆) dissolved in a mixture of organic solvents (mainly carbonates), which must be formulated to match the electrode materials used.

1.2 WORKING OF LITHIUM ION BATTERIES

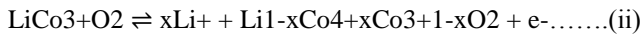
Lithium ion batteries while charging, the positive electrode gives some of its lithium ions, which move to the negative, graphite electrode through the electrolyte and stays there. Electrons also move to the negative electrode but they travel from the outer circuit. During this time the battery stores energy. When no more ions flow across, the battery is fully charged. While discharging, lithium ions move again to the positive electrodes through the electrolyte and the electrons again move through the outer circuit thus supplying power to the outer circuit. When all the previously moved ions have moved back, battery is fully discharged and must be charged again.

The reaction for a LiCoO₂ cathode and a graphite anode is shown below:



The forward reaction represents charging while the reverse reaction represents discharging. It can be broken up into the following half reactions:

At the positive electrode, reduction at the cathode occurs during discharge.



The reaction at the negative electrode is -

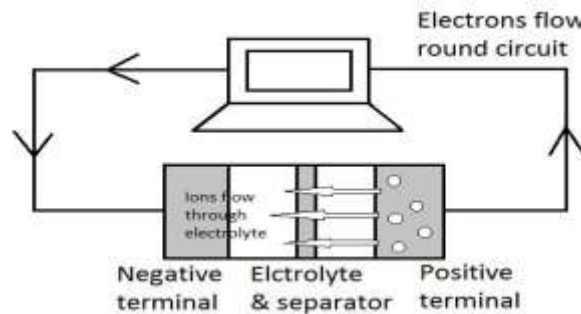
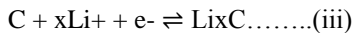


FIGURE 1: LITHIUM ION BATTERIES

1.3 ADVANTAGES

High energy density: The high energy density is one of the chief advantages of lithium ion battery technology. Electronic equipments such as mobile phones needs to operate longer between charges while still consuming more power, there is always a need for batteries with a much higher energy density. The higher power density offered by lithium ion batteries is distinct advantage. Electric vehicles need a battery technology that has a high energy density.

Low maintenance: One of the best lithium ion battery advantage is that they do not require any maintenance to ensure their performance. Ni-Cad cells requires a periodic discharge to ensure that they do not exhibit any memory effect. As memory effect is not exhibited in lithium ion cells, similar maintenance procedures are not required.

No requirement for priming: Some rechargeable cells requires priming when they are charged for the first time. Lithium ion cells and batteries do not require this.

Small in space and lighter in weight: Li-ion battery is lighter than other rechargeable batteries in consideration of battery capacity. This makes it more feasible in portable consumer electronic devices in which physical specifications such as weight and form factor are considered important.

Low memory effect: Li-ion battery have very minimal memory effect. Memory effect is a phenomenon which can be seen in rechargeable batteries in which they lose their maximum energy capacity when repeatedly recharged after being only partially discharged. This memory effect is more common in nickel-metal hydride rechargeable batteries.

. Quick charging: Li-ion battery charges faster than other rechargeable batteries. It actually takes a fraction of a time to charge when compared to its counterparts. [8]

1.4 DISADVANTAGES

Protection required: Lithium ion cells and batteries are not as robust as some other rechargeable technologies. In addition to this, they need to have the current maintained within specified limits. Accordingly one of the disadvantages of lithium ion battery is that they require protection circuitry to ensure that they are kept within safe operating limits. With modern integrated circuit technology, this can be easily incorporated into the battery, or within the equipment if the battery is not interchangeable.

Ageing: The major problem of lithium ion battery for consumer electronics is that lithium ion batteries suffer from ageing. Not only is this time or calendar dependent, but it is also dependent upon the number of charge discharge cycles that the battery has undergone .Batteries can only withstand 500 - 1000 charge discharge cycle before their capacity falls. With the development of li-ion.

Cost: A major disadvantage is their cost. Typically they are around 40% more costly to manufacture than Nickel cadmium batteries. This is a major factor when considering their use in mass produced consumer items where any additional costs are a major issue. [9]

III. LEAD ACID BATTERY

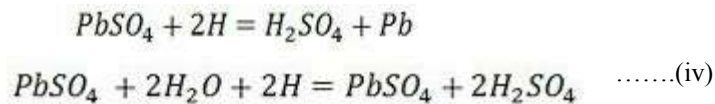
The lead acid battery is a storage device which is use in electric vehicle. Lead acid batteries produce voltage by plates of metals immersed in electrolyte solution. Low cost of lead acid batteries make them suitable for use in electric vehicle to provide high current required to start the motor.

2.1 CONSTRUCTION AND WORKING PRINCIPLE

A lead acid battery consist of two plates of metal one is positive and other one is negative. The positive plate is made of lead and is covered by lead peroxide. The negative plate is made of sponge lead. This two plates are separated by insulating material. These plates are immersed in electrolyte consisting of water and sulfuric acid. [1]

2.1.1 Chemical action using discharging

A load is connected externally between these plates. In diluted sulfuric acid molecule of acid split into positive hydrogen ions and negative sulphate ions. When hydrogen ions reacts with lead peroxide plate the receive electrons from it and become hydrogen atom which again attack lead peroxide and form lead oxide and water this lead oxide react with sulfuric acid and produce lead sulphate. The negative sulphate ions move freely in a electrolyte solution and reach to the pure lead plate where they give extra electrons to the plate and become radical sulphate. As the radical sulphate cannot exist alone it will attack pure lead plate and will form lead sulphate. As



positive hydrogen ions receive electrons from lead peroxide plate and negative sulphate ions gives extra electron to lead plate there would be inequality of electrons between these two plates hence there would be a flow of current to the external load which is connected between these plates for balancing this inequality of electrons. This process is known as discharging process of lead acid batteries.

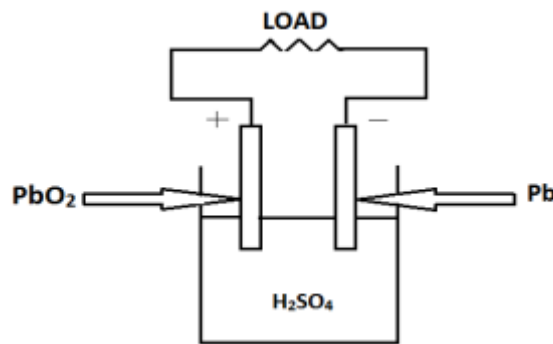
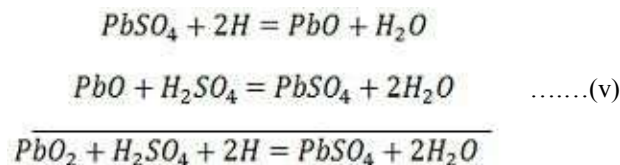


FIGURE 2: Action during discharging

2.1.2 Chemical action during recharging

For charging, lead peroxide and lead plates connected to positive and negative terminal of dc supply mains. During discharging process the density of sulfuric acid decreases but there is sulfuric acid in the solution. This sulfuric acid also remains positive hydrogen ions and negative sulphate ions in the solution. Hydrogen ions being positively charge move to the electrode connected to the negative terminal of dc source ie.lead plate here each hydrogen ions takes electron from plates and become hydrogen atom this hydrogen atom then attack lead sulphate and form lead and sulfuric acid. Negative sulphate ions moves towards the electrode connected to the positive terminal of dc



source ie.lead peroxide plate where the will give up there extra electron and become radical sulphate, this radical sulphate reacts with lead sulphate and form lead peroxide and sulfuric acid hence by charging the lead acid battery become ready for discharging. [2]

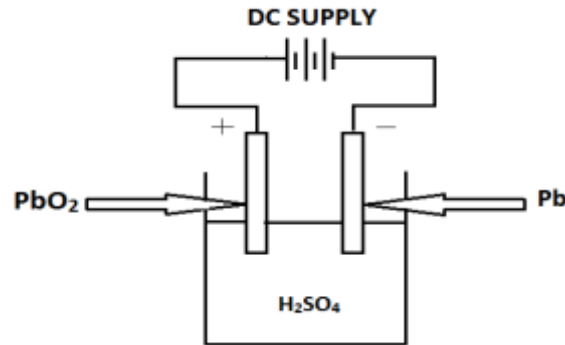


FIGURE 3: Action during charging

2.1 LEAD ACID BATTERY EV APPLICATION

Lead-acid batteries in EV applications being a significant (25–50%) part of the final vehicle. Like all batteries, they have significantly lower specific energy than petroleum fuels—in this case, 30–40 Wh/kg. Lead-acid batteries offer several advantages for EV applications. The batteries are capable of high powers (discharge and charge) and efficiencies, particularly thin plate, valve regulated designs as represented by the spiral wound batteries from Optima Batteries. Electric vehicles used lead-acid batteries due to their technology, high availability, and low cost..[3]

2.2 ADVANTAGES

1. Dilute sulfuric acid is used as electrolyte without flammability. The battery is designed for normal pressure or low pressure with safety.
2. High working voltage, wide operating temperature range, suitable for hybrid electric vehicle (HEV) and other high rate discharge applications.
3. The large-capacity battery technology is mature and can be made into batteries with thousands of ampere-hours, providing convenience for large-scale energy storage.
4. Lead-acid batteries are the cheapest secondary batteries, with unit energy costs about a third of those of lithium-ion or nickel-hydrogen batteries. Scrap batteries have a higher residual value and the recovery price is more than 30% of the new battery.
5. Lead-acid battery has simple composition, mature regeneration technology and high recovery value. It is the easiest battery for recycling and recycling.

2.3 DISADVANTAGES

1. Traditional lead-acid batteries are low in quality and volume energy density. The energy density is only about 1/3 of that of lithium ion.
2. They are large in size and not suitable for light and small in size. The future energy density of lead-acid batteries has great room for improvement mainly for the lead-acid batteries using the new materials and technologies such as carbon foam.
3. The cycle life of traditional lead-acid batteries is short, and the theoretical cycle times are about 1/3 of that of lithium-ion batteries. Lead-acid battery cycle life will be relatively large. There is space for improvement in especially new materials, new structure and new technology lead-acid battery like bipolar lead-acid batteries and lead-carbon battery etc.

4. Lead pollution risks exist in the industrial chain Lead is the main raw material of lead-acid batteries. Lead is accounting for more than 60% of the battery quality whereas lead used in lead-acid batteries can account for more than 80% of the total lead used globally. Lead is a heavy metal and lead acid battery manufacturing industry chain (including primary lead smelting, battery manufacturing, battery recycling and secondary lead smelting) has a high risk of lead pollution. Poor management will cause environmental pollution and harm to human health.

IV.CONCLUSION

From the above detailed study we can compare the batteries on the parameters needed for the electric vehicles. The difference is shown in the table below. From this we can clearly see that lithium ion battery triumphs the lead acid battery for vehicles.

**TABLE 1
 COMPARISON OF BATTERIES**

Sr.No	Parameters	Lithium-ion	Lead Acid
1	Life Span (In Cycles)	5000	300-500
2	High Energy Efficiency	96%	85%
3	Typical state of charge	80%	50%
4	Specific Energy(Wh/kg)	150	40
5	Initial Cost	High	Less
6	FastCharging Time(hours)	2-4	4-8

V.REFERENCES

- [1] New Electric-Vehicle Batteries Henry Oman, Consulting Engineer 19221 Normandy Park Drive SW, Seattle, WA 981 66 (206) 878-4458
- [2] Lead acid batteries Impact on future tin use by ITRI
- [3] Secondary batteries Lead acid battery by David Rand The commonwealth scientific and industrial research organization March 2018
- [4] Lead acid batteries: Key to electric vehicle commercialization by Thomas B.gage
- [5] New technology for lead acid batteries C.Tortora-siger holding SpA-Marcianise (Caserta)-Italy
- [6] Electric vehicle battery swapping by Mhosen Mahoor,Amin Khodaie October 2017
- [7] The energy storage frontier:Lithium-ion batteries and beyond by George Crabtree,Elizabeth Kocs,Lynn Trahey.
- [8] LI-ion batteries:basic,progress and challenges by De Dang
- [9] Electric vehicle battery swapping station coordinated charging dispatch method based on cs algorithm by Jingjing zheng.
- [10] Survey on electric vehicle and battery swapping stations:Expectations of existing and future EV owners by Hrvoje pandzic
- [11] Bo Sun, "Optimal charging operation of Battery Swapping and Charging Stations with QoS Guarantee".
- [12] William Infante, "Optimal Recourse Strategy for Battery Swapping Stations Considering Electric Vehicle Uncertainty".