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Principle, Advantage & Disadvantage of Lead- Acid Battery

Dr. Subrata Naiya, Department of Chemistry, Sushil Kar College, Champahati, Baruipur, South 24 parganas, West Bengal, Pin -743330, India

Abstract

Lead-acid battery is a device that converts electrical energy into direct current electricity. It is also known as storage batteries and has wide applications in Automobiles, Inverters, Electrical Sub-Station, Telecommunication, Solar Photovoltaic system etc. because it has higher cell voltage and lower cost. This article presents Principle, advantage & disadvantage of Lead- acid Battery.

Keywords: Battery, electricity, Automobiles, Inverter, Telecommunication

1. Introduction

A battery is an electrochemical device consisting of one or more electrochemical cells which can store energy in the form of chemical energy. It was invented by Alessandro Volta, an Italian physicist, in 1799[1].It translates to electric energy when the battery is connected in a circuit due to the flow of electrons which are produced by Chemical reactions [2].

Batteries are broadly classified into two categories, namely primary batteries and secondary batteries. Primary batteries can only be charged once [3]. When these batteries are completely discharged, they become useless and must be discarded [3]. Dry cells and (most) alkaline batteries are examples of primary batteries [4]. On the other hand, secondary batteries are the batteries than can be charged and reused for many charging-discharging cycles [5]. The electrochemical reactions that take place inside these batteries are usually reversible in nature. Therefore, secondary batteries are also known as rechargeable batteries [5]. When discharging, the reactants combine to form products, resulting in the flow of electricity [6]. When charging, the flow of electrons into the battery facilitates the reverse reaction, in which the products react

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to form the reactants [6]. Nickel-cadmium (Ni-Cd), lead acid, lithium ion batteries etc., are examples of secondary batteries [7].

Among various secondary batteries the Lead-acid battery is one of the oldest types of rechargeable battery. It was invented by the French physician Gaston Planté in 1859; lead acid was the first rechargeable battery for commercial use. Due to higher cell voltage and lower costing it has wide applications in Automobiles, Inverters, Electrical Sub-Station, Telecommunication and Solar Photovoltaic system [8].

This article has explained working principle, construction, chemical reactions, and applications of lead acid batteries.

2. Construction of Lead–acid batteries

The lead–acid battery consists of two electrodes submerged in an electrolyte of sulfuric acid. The positive electrode is made of grains of metallic lead oxide, while the negative electrode is attached to a grid of metallic lead. Depending on the purpose of use, the number of plates in the electrodes is increased or decreased or their sizes are changed [9]. A sketch of lead–acid battery is given in Fig.1.

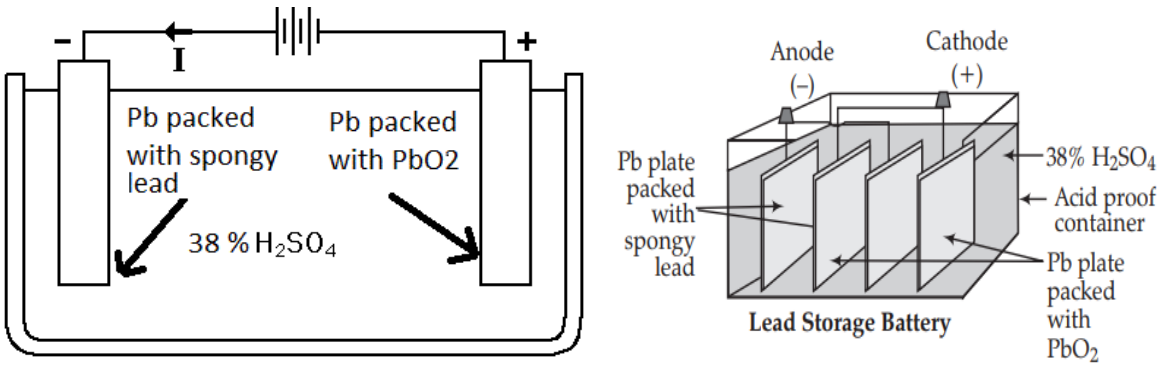

Fig-1: A sketch of lead–acid battery

3. Working principle of Lead–acid batteries

It is a secondary cell, i.e., It operates voltaic cell as well as electrical cell, When operating as a voltaic cell, it supplies electrical energy (discharging) and operates as electrical cell during charging.Lead –acid battery is a reversible battery it can be reused again and again [6].

4. Working principle of Lead–acid batteries for discharging process

When the battery is in the discharged state, then lead sulphate($PbSO_4$) are produced at both electrodes, anode as well cathode by oxidation and reduction reactions respectively. The electrolyte, sulphuric acid loses water. The discharge process gets driven by the electron conduction that occurs from the negative plate back to the cell in the positive plate [10]. This happens in the external circuit. Following reactions take place in discharging process.

Reaction at anode (Oxidation): $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$
Reaction at Cathode (Reduction): $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$
Overall Chemical reaction: $PbO_2 + Pb + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$

5. Working principle of Lead–acid batteries for charging process

The lead acid battery can also be recharged. When the battery is in the charged state, then lead sulphate($PbSO_4$) get oxidized into or lead(IV) oxide at anode and reduced into metallic lead at cathode [11]. The electrolyte contains approximately 4.2M of H_2SO_4.In the recharging process, the electrons are forcibly removed from the positive plate, and they are introduced forcibly in the negative plate [11]. This is done by the source of charging.These reaction are exactly opposite of discharging reaction.

Reaction at anode (Oxidation): $PbSO_4 + 2H_2O \rightarrow PbO_2 + SO_4^{2-} + 4H^+ + 2e^-$
Reaction at Cathode (Reduction): $PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$
Overall Chemical reaction: $2PbSO_4 + 2H_2O \rightarrow PbO_2 + Pb + 2H_2SO_4$

6. Applications of Lead storage batteries

Lead-acid batteries are one of the oldest and most widely used types of rechargeable batteries. They have wide range of applications [12].

i) They are commonly used in automobiles, trucks, and other motorized vehicles due to their ability to provide high-current bursts for starting engines.

ii) In case of power outages or grid failures, lead-acid batteries can serve as a backup power supply, ensuring that essential loads, such as lighting, pumps, and refrigeration systems, continue to function.

iii) Lead-acid batteries are often used for energy storage for hybrid marine power (HMP) & electrical propulsion systems, emergency back-up power or as part of a renewable energy solution. Batteries are also used to start motors for lifeboats, rescue boats & to start emergency generators.

iv) Lead-acid batteries are also used in solar power systems due to their affordability, reliability, and ability to store large amounts of energy. When the sun is not shining or the wind is not blowing, these batteries play a crucial role in balancing the grid and ensuring a reliable supply of renewable energy.

7. Advantages of Lead-acid Batteries

i) Lead-acid batteries are relatively inexpensive compared to other battery technologies, making them a cost-effective choice for solar power systems.

ii) Lead-acid batteries are reliable and durable, providing consistent performance over long periods. They can withstand extreme temperatures and harsh environmental conditions, making them suitable for outdoor applications.

iii) Lead-acid batteries are widely available and easy to source, ensuring easy installation and replacement in solar power systems.

iv) Lead-acid batteries are recyclable and environmentally friendly, with proper disposal methods available to minimize impact on the environment.

8. Disadvantages of Lead-acid Batteries

i) Lead-acid batteries are relatively heavy and bulky compared to other types of batteries, making them unsuitable for portable applications.

ii) Lead-acid batteries have a relatively short lifespan compared to other types of batteries. They typically last between three to five years, depending on usage and maintenance.

iii) Lead-acid batteries require regular maintenance, such as adding distilled water to the electrolyte solution and cleaning the terminals, to ensure optimal performance.

iv) Lead-acid batteries may have slower charge and discharge rates compared to some newer technologies, limiting their suitability for high-power applications.

v) Lead-acid batteries have a lower energy density compared to some newer technologies like lithium-ion batteries. This results in a lower capacity for a given volume or weight.

9. Conclusion:

Despite the development of advanced battery technologies, lead-acid batteries still hold an important place in the market due to their reliability, cost-effectiveness, and longevity. However, it's essential to handle these batteries with caution as they contain harmful substances and should be recycled or disposed of properly to avoid environmental pollution.

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