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Comparative study about valve regulated lead acid (VRLA) battery and Li – ion battery in field of electric vehicle

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Abstract - Electric vehicle technology is the modern era of transportation, how on earth failed to survive and became less preferable to petrol based vehicles catches attention. Collecting data for electric bike failure in market took long time, from different manufactures to different garages. Survey finally ends with conclusion of some faults in fundamentals of electric vehicles, like lack of solid robust construction, cheaper electronic parts, hub motor, and the vital role is of lower battery life results in people's lack of trust on electric vehicle. Due to that reason selection of battery technology is one of the important parameter for electric vehicle manufacturer. The current work towards the application of VRLA and Li – ion battery in field of electric vehicle. The VRLA and Li – ion battery are most successful batteries in electric vehicles. In this review article, VRLA and Li – ion batteries are compared with various aspects i.e. Cost, Safety, Recycling, Energy density, Subzero temperature charging, Startup for EV and Charging flexibility.

Keywords - Valve Regulated Lead Acid (VRLA), Li – ion, Electric vehicles, Battery technology.

Background

Transportation system is a basic requirement of any country. It is increasing rapidly from last fifty to sixty years in our country. Mostly transportation system works on oil based I.C. Engine. So gasoline and diesel are major sources of transportation system. We know that the resources of conventional energy sources are so limited on the earth. These resources will be completely blank within 100 to 200 years. Resources are gradually reducing, due to this reason prices of oil has been started to increase in a world market which affects the economic balance of every country. The recent combination of rising the oil prices and environmental concerns has led to pressure from consumer and government for automotive industries to develop viable alternative option to oil based combustion engine.

Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV) are considering being environmentally free transportation in the mid of rising oil prices and global climates due to green house emissions. The electric vehicle (EV) is propelled by an electric motor, powered by rechargeable battery packs, rather than a gasoline engine. From the outside, the vehicle does not appear to be electric. But Electrical vehicles (EVs) are not popular and successful in market Because of some particular reasons and lack of awareness of consumers toward the Electric vehicles (EV). There are many factors which discourage consumers to purchase Electric Vehicle i.e. speed of E-bike (35 to 40 Km. /h), life of battery (1.5 to 2 years), range of battery (40 to 50 Km.), and Payload capacity. One of the preliminary technical obstacles is the battery life and performance. Batteries of practical size and cost cannot currently complete with vehicle range provided by the gasoline and diesel engine. Consumers demand a battery which provides the longer battery life and better performance in electric vehicles without compromise with prices of battery pack. So, selection of battery technology is key parameter behind the market of electric vehicles.

Introduction

Presently, the VRLA and Li – ion battery are most successful batteries in electric vehicles. The valve regulated battery is an upgrade version of Lead - Acid battery. The Valve Regulated Lead-Acid (VRLA) battery which is called the sealed lead-acid battery is becoming more and more popular in many applications. Because VRLA batteries are mostly sealed, so evaporation of the electrolyte will be reducing due to overcharging, it is a commonly in flooded battery. The electrolyte of the VRLA battery is designed to be immobilized; it means the VRLA batteries will not leak if inverted or if the container is broken. They can be mounted in any orientation and position even immersed in water. The immobilization of the VRLA electrolyte can be achieved by using an absorbent mat separator as well as gelling materials. An accurate charging control is very important for a VRLA battery, especially when charging under high temperature environments. Since, it is not possible to cure the damage caused by overcharge.

Comparative Study

VRLA and Li – ion batteries are compared with various aspects as follow,

(1) Cost
(2) Safety
(3) Recycling
(4) Energy density
(5) Subzero temperature charging

(6) Startup for EV
(7) Charging flexibility

(1) Cost

Li-ion battery is costlier than the VRLA battery because raw metal used in Li-ion battery i.e. lithium and cobalt are more expensive compared to lead used in VRLA battery. Resources of lead are more compare to lithium metal in the earth crust. Recorded reserved resource of lead and lithium are around 2 billion tons and 53 million tons respectively.[1] [2]
For that reason cost of the Lead based battery is lower compared to lithium based battery. Li-ion chemistry is more complex than VRLA chemistry so manufacturing cost is also high.

	VRLA (moderate climate: 25°C)	VRLA (hot climate: 33°C)	Lithium-ion
System size	100 kWh	100 kWh	62.5 kWh
Battery Cost	$12,000 ($120/kWh)	$12,000 ($120/kWh)	$37,500 ($600/kWh)
Cycle Life	1,000 @ 50% DoD	500 @ 50% DoD	1,900 @ 80% DoD
Installation	$20/kWh	$20/kWh	$3.6/kWh
Transportation	$28/kWh	$28/kWh	$5/kWh
Lifetime cost	$0.34/kWh throughput	$0.67/kWh throughput	$0.40/kWh throughput

Fig.: Life time and cost comparison of VRLA and Li-ion battery. [3]

The cost analysis shows that the battery cost of the Li-ion battery is 3 times costlier than the VRLA battery and life time cost of Li-ion battery is 18% higher than VRLA battery.

(1) Safety

Overcharging and fast charging is affect the VRLA battery as well as Li-ion battery. Excessive energy being applied to battery is converted to heat during the overcharging. VRLA battery has vents for releasing the gases generated from the battery during overcharging. So there is no possibility of explosion due to overcharging of battery.
Overcharging and fast charging of Li-ion battery is responsible for explosion of battery. When the Li-ion battery is overcharged, the material inside the battery starts to breakdown and produces the bubble of oxygen and carbon dioxide. So, pressure builds up inside the battery and finally it explodes. [4] Due to that reason, protection circuit must be provided in every Li-ion battery.
Lithium metal is highly flammable in presence of the oxygen. For increasing the energy density of the battery, manufacturers are force to pack more material into electrode and compress it in smaller volume. [5] So, accidently puncturing a battery can cause an internal short and it gets explode.
There are three major aircraft accidents and 160 air craft incidents due to explosion of Li-ion battery were recorded since 1991. [5]

(2) Recycling

VRLA battery is a fully recyclable battery; an internal component contains lead up to 60% of battery mass. So separation process is not required. Recycle process of the VRLA battery is very simple process. Firstly, battery case is broke open and electrolyte is drained out from the battery. Electrodes and connectors are removing from the battery case and recover it whole. The recovered lead is melted and purified to make new components. Key reason for success of recycling of VRLA battery is that all the VRLA battery manufacturer use the same raw material: lead, lead oxide and sulfuric acid as an electrolyte. [6]
Recycling of Li-ion battery is more complicated compared to other battery because Li-ion battery has a wider verity of the material in each cell. The Li-ion battery fed to high temperature furnace along with the slag forming agent. The slag contains lithium, aluminum, silicon, calcium, iron, and manganese. The process of separating the lithium from slag is not an economical process. [6] Manufacturing cost of the Li-ion battery is not high as raw material. Lithium from recycling process is commonly used for other applications, such as lubricating greases (WD-40) and other products. [7]

(3) VRLA battery most preferable battery for starting – lighting – ignition (SLI) in automobile sector. Li-ion battery can not to be replaced with VRLA the battery because of following reasons,

(a) VRLA battery has ability to provide the large amount of current to start up the vehicles. Approximately 10 times current required than the actual capacity of the battery to start the vehicle. Li-ion battery quickly heat up when the large amount of current drains from the battery. There is a thermal protection circuit provided in Li-ion battery which cuts off the power supply due to heating of battery until battery will be cooled enough.
(b) Li-ion battery should not be used in subzero temperature but lead acid battery can be used up to -20 °C.

(4) VRLA battery is most successful battery as a inverter and uninterruptible power supplies (UPS) battery compare to other batteries. VRLA battery is more preferable battery in UPS and inverter because of following reasons,

Inverter and UPS is a constantly connected with the power supply. So battery is continuously charged during normal condition. If battery is continuously charged than a possibility of overcharging. There is a trickle charging method is used to solve the problem of overcharging of VRLA battery. Trickle charging means, charge the battery after 90% of charging at a rate equal to self discharge rate of the battery. Trickle charging is naturally achieved at end of the charging in VRLA battery without any external arrangement.

Other technologies, like the lithium-ion battery technology, are highly intolerant to over-charging, and cannot be charged without an accurate external battery management system.

During the charging process of Li-ion battery, positive ions of the lithium transfer from positive electrode to negative electrode and settle on the layer of graphene. During this phase electron transfer from positive electrode to negative electrode through external charger. When the trickle charging applies to Li-ion battery, free electron forced in to negative electrode. Thus the battery is overcharged in trickle charging method. Normally, Constant Current (CC) charging method and Constant Voltage (CV) charging method with well designed battery management system is used for charging a Li-ion battery. These both charging methods are not possible in inverter and UPS because of constant power supply. So only VRLA battery preferable for the inverter and UPS.

(4) Energy density

Energy density of the Li-ion battery is 2.5 times than VRLA battery. So, it can store more amount of energy compared to VRLA battery in same volume. [8]

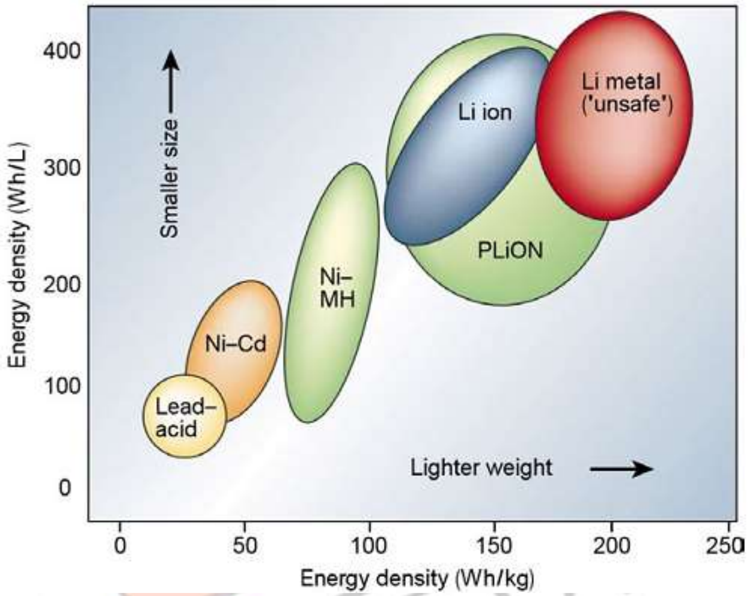

Fig.: Comparison of energy densities and specific energy of different rechargeable batteries.[3]

In above Fig. gives the comparison of energy densities of different commercial batteries, which clearly shows that the Li-ion batteries have a higher energy density as compared to other batteries. Sometimes the high energy density of the Li-ion battery is responsible for the explosion of the battery. [8] Very large amount of charge is stored in the Li-ion battery due to very high energy density. So, battery explodes in case of short circuit or a little defect in battery.

(5) Low temperature charging (subzero temperature)

The electrolyte in VRLA battery becomes highly viscous at subzero temperature so internal resistance of the battery gets increased. So charging and discharging is very slow in VRLA battery at low temperature. [9]

VRLA battery can be charged at subzero temperature up to -20°C at low charging rate The charging is not possible in Li-ion battery at subzero temperature because of reduced diffusion rates on the anode. [10]

- Cathode (+Ve) Lithium metal oxide: Lithium cobaltate (lithium cobalt oxide), Lithium maganatate (Lithium manganese oxide), and Lithium iron phosphate.
- Anode (-Ve): Graphite (Carbon).

The internal resistance of the Li-ion battery depends on bulk resistance (R_b), surface layer resistance (R_{sl}) and charge transfer resistance (R_{ct}). Among these three components, the R_{ct} increase most significantly and becomes predominant as the temperature falls below -10 C. The performance of the Li-ion battery is very poor at low temperature due to high charge transfer resistance (R_{ct}) of the graphite at anode. [11]

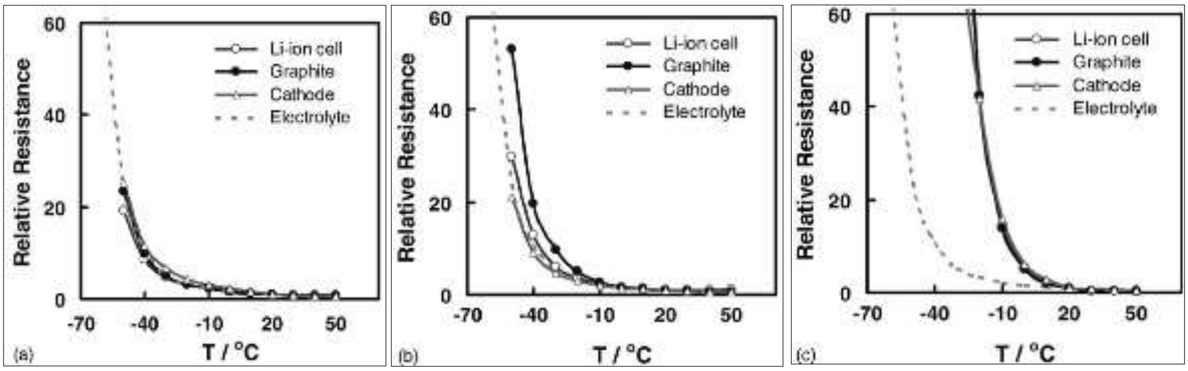

Fig. (a): bulk resistance (R_b) (b) surface layer resistance (R_{sl}) (c)charge transfer resistance (R_{ct})

So, VLRA battery is optimal solution for various types of applications at subzero temperature. Like radio communication system, telephone backup power, portable test equipment etc.

(6) Startup for EV

Electric vehicle have a high vehicle mass to passenger mass ratio. So it requires a high power from electric motor.[12] Electric motor required a large amount of current to carry the vehicle. VRLA battery is deep cycle battery means it has a high specific power.[12][13] So VRLA battery is capable for high discharging current to run the electric motor. Li-ion battery quickly heat up when the large amount of current drains from the battery. So, Li – ion battery is not suitable for electric bike.

(7) Charging Flexibility

Charging for VRLA battery is more flexible and tolerant to improper recharging than Li-ion batteries in terms of risk of damage to self and property.[12] Li-ion can't handle overcharging condition. There requires a special arrangement of protection circuit to control overcharging and overvoltage in Li – ion battery. Its increases the expensive cost further. On other hand lead-acid batteries can handle overcharging perfectly. There is forming a hydrogen gas from VRLA battery during overcharge condition.

References

[1] "Aviation Cargo and Passenger Baggage Events Involving Smoke, Fire , Extreme Heat or Explosion Involving Lithium Batteries or Unknown Battery Types.", FAA Office of Security and Hazardous Materials Safety, May – 2017.
[2] David E. Guberman, "Lead - Mineral Commodity Summaries.", U.S. Geological Survey, January 2017.
[3] Greg Albright, Jake Edie, Said Al-Hallaj, "A Comparison of Lead Acid to Lithium-ion in Stationary Storage Applications.", Report Published by AllCell Technologies LLC, March – 2012.
[4] Sarah Fecht, " Article in Popular science: This is what happens inside a battery right before it explodes.", [online], Available at, https://www.popsci.com/this-is-what-happens-inside-battery-before-it-explodes
[5] Chemistry, Electronics & systems, Safety, "Article: Are lithium ion batteries becoming unsafe?", [online] December – 2014, Available At, https://qnovo.com/are-lithium-ion-batteries-becoming-unsafe
[6] Brian W. Jaskula, " Lithium - Mineral Commodity Summaries.", U.S. Geological Survey, January 2018.
[7] Linda Gaines, "The future of automotive lithium-ion battery recycling: Charting a sustainable course.", Journal of Sustainable Materials and Technologies [ELSEVIER], November – 2014, PP. : 2 – 7.
[8] S.S. Zhang, K. Xu, T.R. Jow, "The low temperature performance of Li-ion batteries.", Journal of Power Sources [ELSEVIER], November – 2003. PP. 137–140.
[9] Da Deng, "Li- ion batteries: basics, progress, and challenges.", Energy Science and Engineering -2015; August 2015, PP: 385–418.
[10] Deborah Diemand, "Automotive Batteries at Low Temperatures.", cold regions technical digest, USA Cold Regions Research and Engineering Laboratory, Hanover, May – 1991 PP: 5 -7.
[11] Battery University, "Article: Charging Batteries at High and Low Temperatures" [online] Available at: http://batteryuniversity.com/learn/article/charging_at_high_and_low_temperatures
[12] S.S. Zhang, K. Xu, T.R. Jow, "The low temperature performance of Li-ion batteries.", Journal of Power Sources [ELSEVIER], November – 2003. PP. 137–140.
[13] Linda Gaines, "The future of automotive lithium-ion battery recycling: Charting a sustainable course.", Journal of Sustainable Materials and Technologies [ELSEVIER], November – 2014, PP. : 2 – 7.
[14] Battery University, "Article: Battery Recycling as a Business." [online], Available at: http://batteryuniversity.com/learn/article/battery_recycling_as_a_business

[15] Jonathan X. Weinert, Andrew F. Burke, "Lead-acid and Lithium-ion batteries for electric bikes in China: Implications on the future growth of electric-drive vehicles." Journal of Power Sources [Researchgate], October 2007, PP: 938-945