Characterization and Optimization of Lithium Iron Battery for Current EV Battery Technologies

Chinababu Anima [1], A. Sai Kanishka[2], Prof. K.T Balaram Padal[3]

[1] *Research Scholar, Andhra University College of Engineering, Visakhapatnam India*

[3] *Professor, Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh, India*

Abstract-The current battery technologies present across the globe has the lithium ion as the major material used to manufacture and maintain the batteries, this led to huge demand and the shortage of the lithium for the future. Lithium-Ion batteries have less maintenance, high energy density, and low self-discharge which makes the manufacturers and users get more inclined to it. Lithium Iron Phosphate batteries do tend to have all the advantages with the lithium ion, and some of the class leading features too. It can be an alternative to the lithium ion, and has the good potential to be as a replacement to it too. Lithium iron batteries are high in energy density i.e., the storage of the charge in the battery is not compact, thus the chemicals which are used in the lithium iron phosphate are also explosion resistant Which tends to create free-ness in the battery. It also has high Vander walls radius. It contributes to the better cooling. So, this battery can be a predominant replacement to the existing lithium-ion batteries. This paper mainly focuses on the introduction of various battery technologies, various testing measures such as Discharge rate, battery consumption, Thermal properties, and Charging test done on the lithium ion and lithium iron phosphate batteries, and comparing them.

Keywords: Lithium-Ion Battery, Lithium Iron Phosphate, Optimization, Efficiency, EV Batteries

Literature Review

Lithium-ion batteries need little maintenance, which is something that most other chemistries cannot argue. There is no memory, and there is no need for planned cycling to extend the battery's life. Furthermore, as opposed to nickel-cadmium, lithium-ion has a lower self-discharge, making it suitable for modern fuel gauge applications. As lithium-ion batteries are discarded, they do little damage [1]. The Li-ion battery has strong fundamental advantages and has been built into the high energy density, high cycle life, and high-performance battery that it is today thanks to decades of testing. There are a variety of interesting anode and cathode products on the market, but all of them have weak electrical conductivity, sluggish Li transfer, dissolution or other unfavorable interactions with the electrolyte, low thermal stability, high volume expansion, and mechanical brittleness. [2]. Some of the data about the usage of batteries in different electric-based appliances is shown below:

- **TeslamodelS**:LiNiCoAlO2,whichcomprisesofthe nickelinn80%composition,and 15 % of cobalt and the remaining 5 % comprises ofAluminum.
- **Apple iPhone**: LiCoO2 which comprises of cobalt in 100%composition
- **Nissan Leaf**: LiMn2O2 which comprises of manganese in 100%composition
- **Tesla Power wall**: LiNiMnCoO2 which comprises of manganese, nickel, cobalt in equal composition's, i.e., in33.33% [3] [4]

The sodium nickel chloride, nickel aluminum, and lead acid batteries, among others, are used in a wide variety of applications. However, owing to their benefits, lead acid batteries are projected to become the preferred battery in electric cars in the immediate future. The high strength, range, and weight of the batteries are some of the sacrifices. LiFePo4 can be a good replacement for conventional lithium-ion batteries.

Methodology:

Investigation **of various battery technologies:** The primary focus of this chapter was on the investigation of various battery technologies that are commonly found in electric cars. This entails a review of the literature as well as the research and study of realistic data on different batteries, such as energy discharge, range, and cooling.

Content Range for Optimized Batteries: The issue statement is established and analyzed after the investigation of different battery technologies. The biggest issue with batteries is that they appear to heat up fast and have a lower capacity discharge, so range decreases quickly and charging takes longer. Lithium Iron Phosphate is chosen to act and refine in order to solve this.

Characterization and Optimization: Phosphate battery is studied and the concentration:Various materials which are used in thelithiumiron is noted. Upon further the optimized composition is suited to betterefficiency.

Comparison Between Lithium Iron Phosphate And Lithium-Ion Battery:

The lifecycle of lithium iron phosphate is 1,000-10,000 days. These batteries can withstand extreme temperatures with little harm. For applications of embedded systems or that must operate for long periods of time before being recharged, they have a long life.

The higher energy density of lithium-ion makes it more unstable, particularly in higher operating temperature environments. It has a 500-1,000 cycle life cycle because the operating temperature of the electronics or working components will adversely affect it.

As compared to nickel metal hydride and nickel cadmium batteries, lithium batteries are currently more expensive. However, the long life of lithium batteries will offset the high initial costs. The below are the advantages of LiFePo4:

- Lithium-ion batteries have the highest energy efficiency.
- Lithium iron phosphate has a high energy density and a long-life span.
- No thermal runaway and safe when fully charged: lithium iron phosphate
- Stable chemical and thermal chemistry: lithium iron phosphate
- Lithium-ion batteries are lightweight and portable.
- Lithium iron phosphate and lithium-ion have long lives; lithium iron phosphate and lithium-ion have low costs.

The analysis of the lithium-ion battery is done. The results of the lithium-ion battery are mentioned below: they include the testing of the 100Ah 12V battery and 24V 100Ah battery. The results such as optimal voltage, optimal temperature is available in this given data mentioned below:

Lithium Battery type:	12V–100AhLithium-Ion Battery	24V – 100Ah Lithium-Ion Battery
Nominal capacity Nominal battery voltage	100Ah 12 VDC	100Ah 24 VDC
Operation voltage discharge	9.2 VDC	18.4 VDC
Operation voltage charge	15 VDC	30 VDC
Cell voltage min cut-off	2.3 VDC	2.3 VDC
Cell voltage max cut-off	4.2 VDC	4.2 VDC
Continuous discharge current	100 A	100 A
Operating temperature	- 40°C~+50°C	-40°C~+50°C
Cooling	Forced fan	Forced fan

Table 1: The above table represent the lithium-ion battery characteristics

Some of the predominant advantages if the lithium iron phosphate batteries are mentioned below:

Power Density: Lithium iron phosphate batteries (LiFePO4) have a high-power density, which allows them to be compact and light. Lithium batteries have a high energy density and are at least half the weight of lead-acid batteries.

Efficiency: Lithium iron phosphate batteries (LiFePO4) are highly effective, with 100% of their energy available. Furthermore, their quick charge and discharge speeds make them ideal for a wide range of applications.

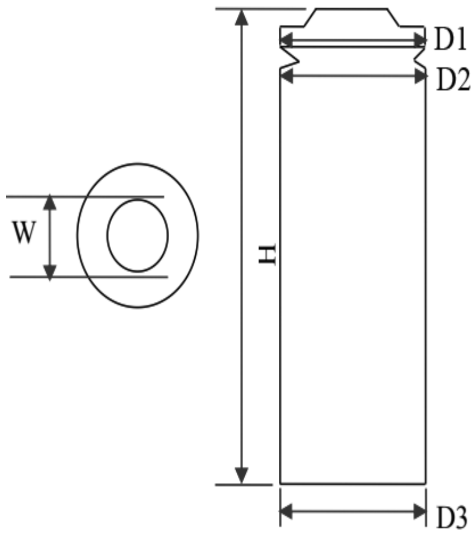
Maintenance: To prolong the life of lithium iron phosphate batteries (LiFePO4), no active maintenance is needed. Furthermore, the batteries have no memory effects and can be retained for longer periods of time due to low self-discharge (3% per month). Lead-acid batteries require extra care. If they do not, their life expectancy would be reduced even more.

Temperature: Lithium iron phosphate (LiFePO4) can work at a wide range of temperatures, making lithium batteries ideal for a variety of applications, including those that require high temperatures. Lithium is the safest option for devices that would deplete the battery or operate in harsh weather.

Post the selection of the battery (Lithium Iron Phosphate) it is subjected to certain tests like Temperature Measuring, Voltage measuring, charge and discharge measuring and etc. these are done using the below equipment's:

PackageDimensions:

Fig 2.0 The above figure shows the dimensions of the sample battery



Items	Size(mm)	Tolerance(mm)
Width	15. 92	±0.1
Height	70. 5	0.4
		-0.2
Diameter 1	32. 15	±0.05
Diameter 2	32. 5	±0.3
Diameter 3	32. 4	±0.1

Instruments Use to conduct Test:

1) 3.75V to 4.8V and 3amp to 6Amp Power Adapter/ to check Charging capacity The nominal voltage of this battery is 3.2V and 3000mah capacity which is set by the manufacturing company for retaining long self-life and prevent voltage lose, with this 3amp charging capacity adapter (0.5C charging Capacity) it will take 1hr to fully charge the battery from its nominal stage, over all time 2hrs to fully charge, 6Amp is the 1C capacity and it will take 1 hrs. to fully charge the battery.
2) Brushless Motor and some power Resistor for load/Discharge test.
   This is load which we apply to drain the battery, it is just opposite as charging, if we drain the battery with 6amp continue current it will discharge the battery in 1hr and we can drain it 2c and 3c level for 20min discharge.
3) Liitokala Battery balancing unit to analyse the Battery voltage and ampere.
   It's easy to level 1 individual battery for charging and discharging, when you connect it to series and parallel it must be working as a 1

unit, must need to match the cell capacity and voltage to connect. With this kind of battery capacity tester, we making all individual cell balance for maximum performance

4) Digital Thermometer to measure constant temperate.
While charging and discharging by 3C level must need to monitor the temperature it should not increase by its maximum limit

Results And Discussions

The lithium iron phosphate batteries are subjected to various tests. It has been observed that the following are the data obtained. The testing is done on the lithium iron phosphate (LiFePO4) Battery 32700 model which has 6000 mAh Capacity. The results were mentioned below:

Nominal capacity of battery: 6000 mAh or6Ah
Nominal Battery Voltage:3.2V
Charge Voltage:3.65V
Operational Voltage Discharge:3.65V to2V
Operational voltage charge: 2V to3.65V
Cell Voltage Max cut-off:2V
Max Discharge impulse current in 10 min, 5min, 20 sec 3C and5C
Continuous Charge Current:0.5C
Standard Charge:0.5C
Standard Discharge Current:0.5C
Rapid Charge Current:1C
Rapid Discharge Current:1C
Life Cycle:2000
Storage Temperature: 0C' to35C'
Operating temperature: -10c' to60C'
No. of inputs andoutputs
Self-discharge rate permonth:
After 3 months' storage ≥5.7Ah
After 6 months' storage ≥5.6Ah
After 12 months' storage ≥5.5Ah

- The battery is charged at a 3 C constant current with a voltage limit of 4.8V for 8 hours after fully charged, there will be no problem regarding fire outburst and explosion. Maximum Temperature of battery surface should not exceed 150°C
- Weight of Cells:141 Grams

The charging details of the battery are provided below:

- Charging Voltage 3.75 V to 4.8V (Ideal will be 3.65V)
- Regular Charging: 0.5C 3Amp Current will take 2 Hours to full charge the 6000mahbattery
- **Fast Charging**: 1.0C 6Amp Current will take 1 Hour to full chargethe 6000mahbattery

When the characteristics of lithium Iron and lithium ion are compared, it is observed that the lithium iron phosphate have relatively low discharge when compared to peers. It also has the lowest discharge per month rate. The operating temperatures of LiFePo4 is also high considering its quintessential thermal properties. The results are analyzed and produced in the graphs and they are mentioned below:

GRAPH 1: This graph represents the relation between the voltage and the battery charge percentage, when the battery is subjected to charging the voltage is supplied to the battery in the initial battery percentages is high (10-17%). Post that it is steady, and the peak increases at 90%. the discharge rate is inversely proportional to discharge rate. It can be concluded that the initial and the final peak regions do require quite a bit of time whereas the mid-range battery capacity can be quickly charged up. This battery pack also supports pulse charging.

GRAPH 2: The graph indicates the relation between charge and discharge rates with the voltage. It's observed that the charging/discharging rate is steady at 1C. If the charging is done at higher pulse rates (2C, 3C) the discharge is also high. The blue and yellow curves are ideal. the one which charges quickly do tend to discharge briskly after 80% of battery percentage. The median charge rate 1C starts at a voltage of pretty good voltage rate and then slowly picks up the flow and tend to get charged with full battery percentage in a constant charge rate.

GRAPH 3: This represents the relation between the voltage and battery capacity in percentage with respect to the different operating temperatures. It is pretty much clear form the observation that the temperature is constant at the constant flow charge rate. When the battery is tend to charge quickly through higher voltage the temperature too increases rapidly.

It also indicates the temperature of the battery at the pre-required battery percentage. i.e., at the 100% of charge via constant flow, the battery will be at 0º C and at 20% of battery charge the temperature will be around -30ºC, so does the voltage at 2.5V

GRAPH 4: The graph shows the relations between the battery capacity and mAh. Post the life cycle of battery, the charge storage capacity of lithium iron phosphate battery decreases slowly when compared to lithium ion and lead acid (it drains fast post the end-of-life cycle). This shows the reliability factor of liFePo4 batteries

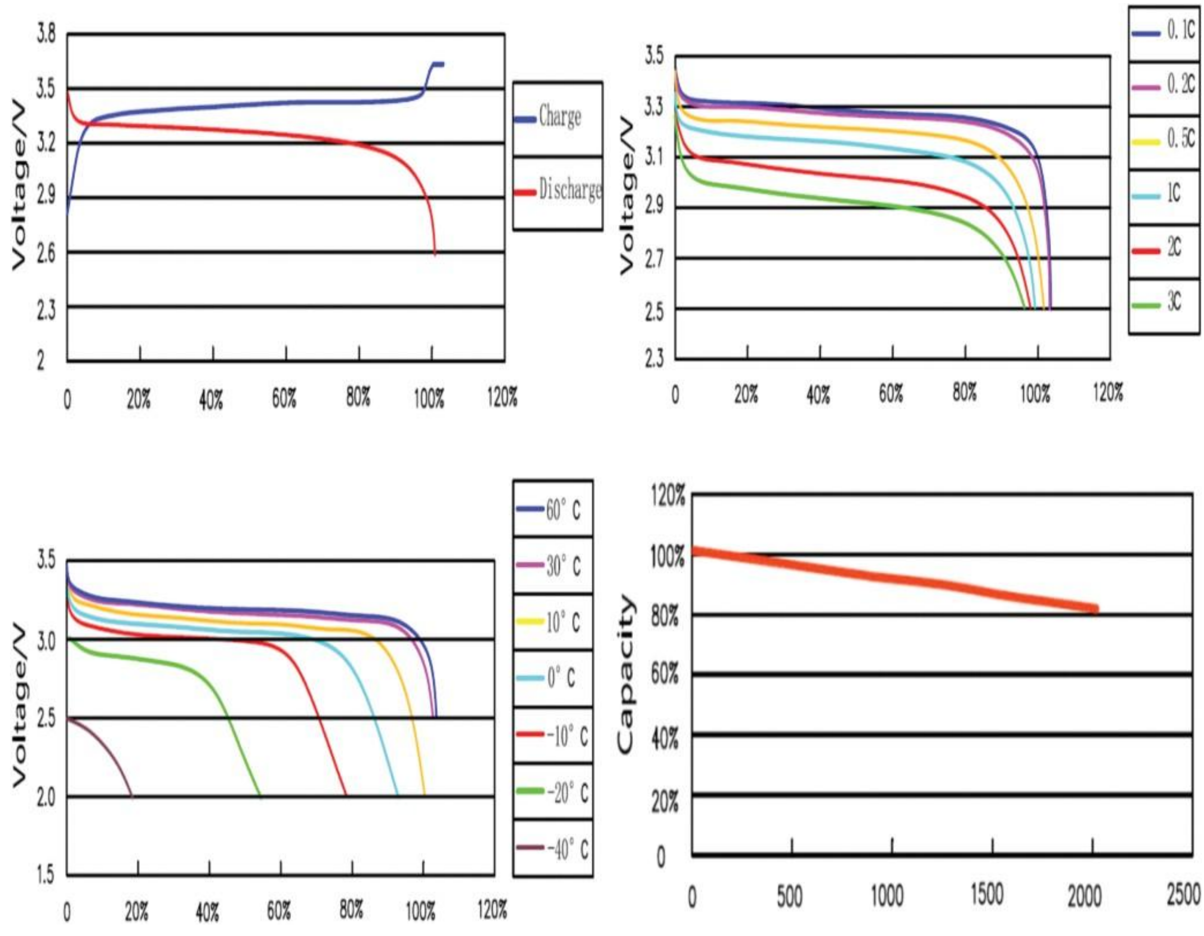
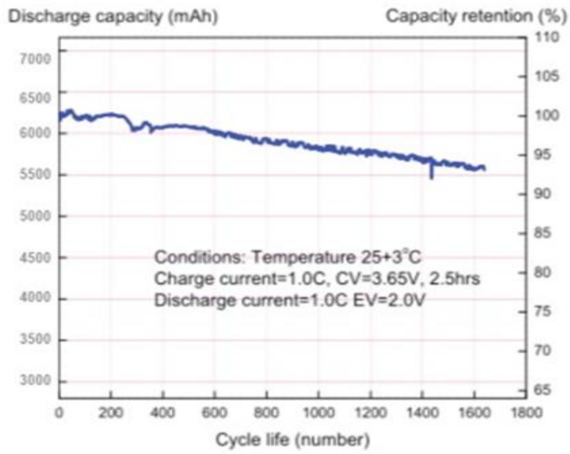
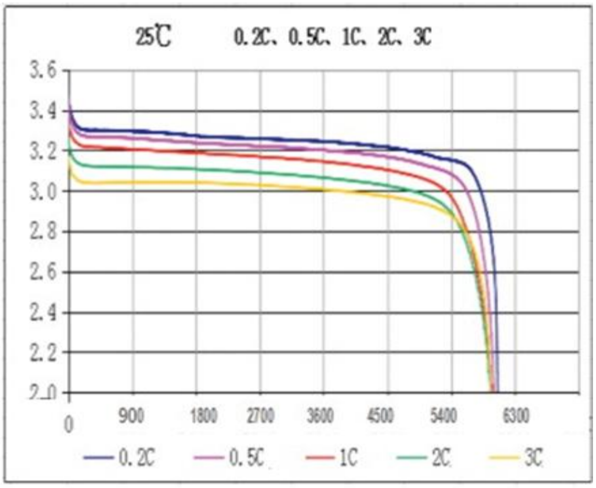
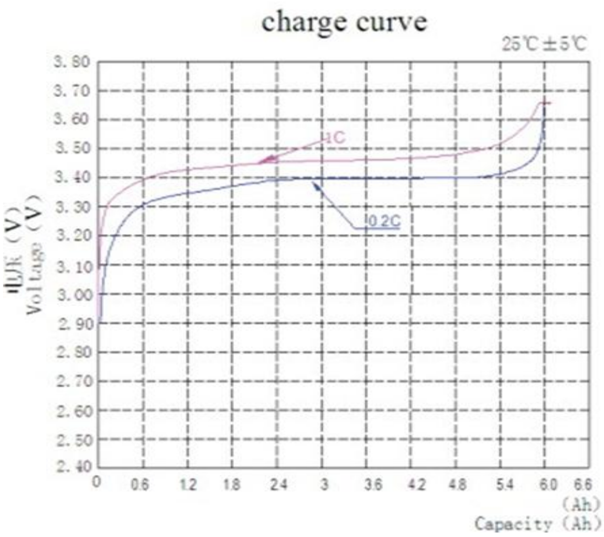


Fig 3.0 The above figure shows various relationship characteristics of batteries.

GRAPH 5: The graph shows the relation between charge relation in percentage and the life cycle number at an operating condition of 28ºC and charge 1.0 C. initially the battery capacity percentage is 100% at initial life cycles, but slowly with the increase in life cycle number the battery composition tend to change i.e. After the median life cycle number 1200 the capacity has gone down from 100% to 96%. After the 1600 cycles it has reached to 91%. This can be concluded that post the life cycle of battery, the charge storage capacity of lithium iron phosphate battery decreases slowly.







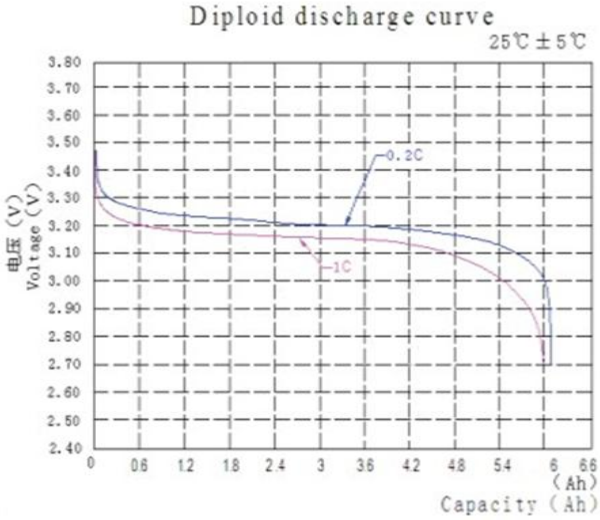


Fig 4.0 the above graphs represent the relations between different battery characteristic's

GRAPH 6: This graph is same as graph 2. But in the graph 2 the relation is shown in between the voltage and the battery percentage. But in graph 6, the relation is shown between the voltage and the battery capacity in mAh. Excluding this, all of the relations are same between them.

The graph indicates the relation between charge and discharge rates with the voltage. It's observed that the charging/discharging rate is steady at 1C. If the charging is done at higher pulse rates (2C, 3C) the discharge is also high

GRAPH 7: 2.8V is the stage where battery is fully discharged or we can say it is an empty mode. When battery is empty it has a no ampere hour capacity left, the charging graph shows that when voltage increase, which means that the ampere hour capacity will also increase, when battery is fully charged, it's observed to be having 3.65 voltage as well as 6000 mAh or 6Ah capacity. If the battery voltage is 3.4 volt it means it has 3000mAh or 3ah capacity. 1C, 2C, 3C is the charging speed as well as discharging, 3c is the faster 3time faster than its actual capacity,

GRAPH 8: It's called as Discharge Curve. This shows the relation between the battery voltage and the capacity in Ah at a discharge rates of 1C and 0.2C, it is just opposite of Charging Curve, when battery is fully loaded/charged it has 3.65V and 6000mAh or 6Ah capacity, when discharging start its losing its voltage and mAh capacity, if the during the battery discharging time if the voltage shows 3.2V it means it has half capacity left which is 3000mAh or 3Ah

Conclusion:

This paper mainly focused on the introduction of the battery materials. Post the introduction the study on the two predominant battery types, lithium-ion battery and lithium iron phosphate is done. The experimental study is done on both the material types to study them. It's observed that the lithium iron phosphate (LiFePo4) has the best battery power storage rate, and considerably less battery discharge. Due to it light in weight feature LiFePo4 has the better efficiency. It also has the best operating temperature range. The charge storage into conventional lithium batteries is in a compact way, i.e., the charge is squeezed into the unit. In lithium-iron phosphate the charge distribution is free due to its higher Vander walls radius, due to this it has the better thermal properties than the conventional lithium batteries. LiFePo4 also supports "pulse charging" which helps modern vehicles to get maximum charge in less time. Storage of LiFePo4 is pretty much easy and reliable, due to its less discharge rate and blast proof nature.

References

[1] Thele M. Evaluation of Li-ion batteries in 14 V architectures. In: 3rd advanced automotive battery conference, Europe, Mainz, Germany, 18–22 June 2012. Oregon, House, California: Advanced Automotive Batteries,2012.

[2] J. McDowall, Conventional battery technologies-present and future, IEEE Power Engineering Society Summer Meeting, Vol. 3, 2000.

[3] D. Linden and T. B. Reddy, Handbook of battery, 3rd ed. McGraw Hill, 2002.

[4] K. Hechtfischer, Advanced Battery Technologies for Automobiles and their Electric Power Grid Integration, HDT Conference, Essen, Jan. 2009.

[5] Z.M Salameh and B.G. Kim, Advanced Lithium Polymer Batteries, IEEE General Meeting, Calgary, 2009.

[6] J. Larmine, J. Lowry, Electric vehicle technology explained, John Wiley and Sons, LTD, 2003.

[7] H. A. Kiehne, Battery technology handbook, Expert Verlag, New York, Second Edition 2003