JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Design and Thermal Analysis of Lithium Ion Battery for Electrical and Hybrid Vehicles Application

[1]Satyendra Kumar Tiwari, [2]Prof. Amol Tripathi
[1]Research Scholar, [2]Assistant Professor
[1&2]Department of Mechanical Engineering
[1&2]Rewa Institute of Technology, Rewa, India

Abstract : The future of the automotive industry mainly depended on renewable energy because of the lack of fossil fuel. Due to the lack of fossil fuel and pollution arises due to fossil fuel; introduce a new path for the automotive world. The electric-powered vehicle is one of them. Properties of a lithium-ion battery are very higher than other batteries so that it should be controlled and maintained properly to achieve its maximum performance. This paper investigate the design and thermal analysis of lithium ion battery for electrical/ hybrid vehicles application. The Ansys 19.3 software used to analysis the performance of the model. Simulation results shows improvement in the proposed model in terms of the optimized parameters.

***IndexTerms* - Lithium Battery, ANSYS, Vehicle, Temperature, Thermal, Power, Material.**

I. INTRODUCTION

A battery is a source of electric power consisting of one or more electrochemical cells with external connections [1] for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode.[2] The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy.[3] Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.[4]

Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smart phones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting electrical energy to mechanical work, compared to combustion engines.

Batteries convert chemical energy directly to electrical energy. In many cases, the electrical energy released is the difference in the cohesive[13] or bond energies of the metals, oxides, or molecules undergoing the electrochemical reaction.[3] For instance, energy can be stored in Zn or Li, which are high-energy metals because they are not stabilized by d-electron bonding, unlike transition metals. Batteries are designed so that the energetically favorable redox reaction can occur only when electrons move through the external part of the circuit.

A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing metal cations. One half-cell includes electrolyte and the negative electrode, the electrode to which anions (negatively charged ions) migrate; the other half-cell includes electrolyte and the positive electrode, to which cations (positively charged ions) migrate. Cations are reduced (electrons are added) at the cathode, while metal atoms are oxidized (electrons are removed) at the anode.[14] Some cells use different electrolytes for each half-cell; then a separator is used to prevent mixing of the electrolytes while allowing ions to flow between half-cells to complete the electrical circuit.

The voltage developed across a cell's terminals depends on the energy release of the chemical reactions of its electrodes and electrolyte. Alkaline and zinc–carbon cells have different chemistries, but approximately the same emf of 1.5 volts; likewise NiCd and NiMH cells have different chemistries, but approximately the same emf of 1.2 volts.[20] The high electrochemical potential changes in the reactions of lithium compounds give lithium cells emfs of 3 volts or more.

Research areas for lithium-ion batteries include extending lifetime, increasing energy density, improving safety, reducing cost, and increasing charging speed, among others. Research has been under way in the area of non-flammable electrolytes as a pathway to increased safety based on the flammability and volatility of the organic solvents used in the typical electrolyte. Strategies include aqueous lithium-ion batteries, ceramic solid electrolytes, polymer electrolytes, ionic liquids, and heavily fluorinated systems.

Life of a lithium-ion battery is typically defined as the number of full charge-discharge cycles to reach a failure threshold in terms of capacity loss or impedance rise. Manufacturers' datasheet typically uses the word "cycle life" to specify lifespan in terms of the number of cycles to reach 80% of the rated battery capacity. Inactive storage of these batteries also reduces their capacity. Calendar life is used to represent the whole life cycle of battery involving both the cycle and inactive storage operations.

II. BACKGROUND

The temperature of lithium-ion battery is critical for battery life-span and safety reliability. At present, the widely used temperature measuring method can only measure the surface temperature of the battery, but cannot measure the actual temperature inside the battery. Besides, the method is greatly affected by ambient temperature, and the accuracy is limited. To solve the above problems, we proposed a new noninvasive temperature measuring method based on magnetic nano particles for electric vehicle lithium-ion battery. At first, the mechanism of magnetic nano particles for battery temperature measurement was studied. Then, a temperature measuring model was established. Excitation and measurement system of AC magnetic field was built for temperature measuring experiments. The test results demonstrated that the proposed method could accurately measure the internal temperature of the battery, (X. Liu, W. Chen, J. Liu, W. Li and R. Yan 2018).

Battery performance is strongly dependent on the ambient temperature. For example, at moderate temperatures, the battery performance is optimal, whereas at extreme temperatures, the battery performance is not optimized and sometimes unexpected. In order to predict the battery behavior, a model that involves the battery's underlying dynamics is usually used. The majority of dynamic battery models are derived at only one single temperature (room temperature), which can easily lead to failure in predicting the battery performance when the temperature varies. Therefore, adding some temperature dependence to those models can make the battery management system more reliable, safer, and moreover, prolong the battery lifetime. In this work, a 3.6V/1100mAh lithium-ion (Li-ion) battery cell is tested at temperature between -30°C and +50°C and its main parameters are measured. The measured parameters include the discharge capacity, the charge and discharge resistance, and the open-circuit voltage, which comprise the main parameters of equivalent electric-circuit based models. Experimental testing results and observations are presented in this work (A. A. Hussein et al., 2018).

Since the initial report by Legagneur et al. (2001), very few articles have been published until 2010. Aravinden et al. (2010) studied the electrochemical performance of pure and carbon coated $LiMnBO_3$ material. Solid state synthesis method was adopted and adepic acid was used as a carbon source to synthesize carbon coated $LiMnBO_3$ material. Pure and coated $LiMnBO_3$ delivered an initial discharge capacity of 58 mAh g^{-1} and 111 mAh g^{-1} respectively. The carbon coating on the surface of the $LiMnBO_3$ significantly improved the electrical conductivity of the $LiMnBO_3$ material (Vanchiappan Aravindan, Kaliyappan, Samuthira Pandian and Lee, 2010).

Kim et al. (2011) investigated the structural stability and electrochemical properties of hexagonal and monoclinic $LiMnBO_3$. Density functional theory (DFT) with generalized gradient approximation and Hubbard U corrections (GGA + U) approach was used to predict voltages and phase stability. The electrochemical properties of the monoclinic $LiMnBO_3$ were studied and the discharge capacity of 100 mAh g^{-1} was obtained. (Kim, Jacob Moore, et al., 2011).

Seo et al. (2011) performed the first-principles calculation and studied the electrochemical properties of three isotopic $LiMBO_3$ compounds (M = Mn, Fe, and Co). The theoretical energy density was calculated (660 – 860 Wh kg^{-1}) and low volume change (less than 2%) during cycling was observed. The electronic structure investigation suggested that the small polaron acted as a main conductor in Li_xMBO_3. Li mobility in Li_xMBO_3 crystal structures was thought to be by zigzag one-dimensional (1D) Li diffusion tunnels (Seo et al., 2011).

III. METHODOLOGY

The main contribution of the proposed research work is as followings-

- To design lithium Ion battery using solid work software.
- To analysis using the Ansys software.
- To analysis the simulation of the battery and calculate the performance parameters.

The Computer-based method is called the analysis of thermal temperature is to identify how a product responds to real-world condition, vibration, heat, fluid flow as well as other physical effects. As finite elements analysis has become more accessible, many researchers have looked for ways to use it to calculate stress analysis. Each has their own unique details, but the general formula is to alternate between a finite elements analysis to determine pressures and calculate of wear which adjust the model prepared in the analysis. Using here is the engineering simulation program developed by the United States called the ANSYS Workbench platform that is a subsidiary part of ANSYS 19.3. ANSYS Workbench was chosen as the FEA software package because of its ability to accept a 3D computer aided design (CAD) model. The program also allows for the accurate placement of contact temperature and brake pressures, in addition to the modeling of contact surfaces.

In thermal FEA models, choices of elements size, shape and order, as well as high Biot number convective loads, can sometimes result in non-physical temperature results such as temperatures that are higher or lower than any applied temperature. In transient models, the use of small time substeps can amplify the effect with high-order elements.

Fewer problems of this sort are seen in thermal models that use low-order elements such as 4-node tet elements and 8-node brick elements. Related structural FEA models of the same geometry can use high-order structural elements, and recent versions of Ansys Mechanical Workbench, such as v14.0, can map temperatures between the non-matching meshes. There are a number of user-set controls for how the mapping is performed.

Difficulties in thermal responses will still be occasionally seen with low-order thermal elements. The use of layers of elements that are thin at exterior surfaces can be used in attempts to address this (reducing the Biot number). The difficulty may also sometimes be seen in thermal elements that have different convective loads on two faces of one element. Work-around methods could include small elements on edges, or a small strip on one side of an edge with no convective load applied.

The Ansys Mechanical APDL interface has mapping methods for temperatures using the BFINT command. The mapping methods available in the most recent Workbench Mechanical interface are more advanced, and offer higher success rates for mapping between non-matching meshes. In this way, many non-physical thermal response difficulties can be avoided, while still performing related structural analyses with high-order elements.

Table 1: Units

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

IV. MODELING AND SIMULATION RESULTS

The modeling and simulation is performed in Ansys 19.3 software.

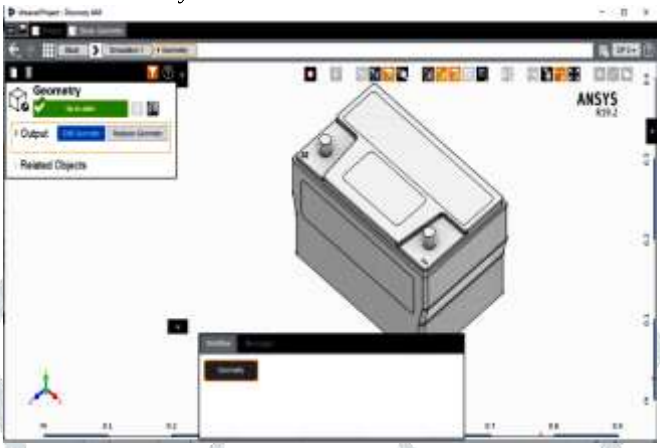

Figure 1: Model design

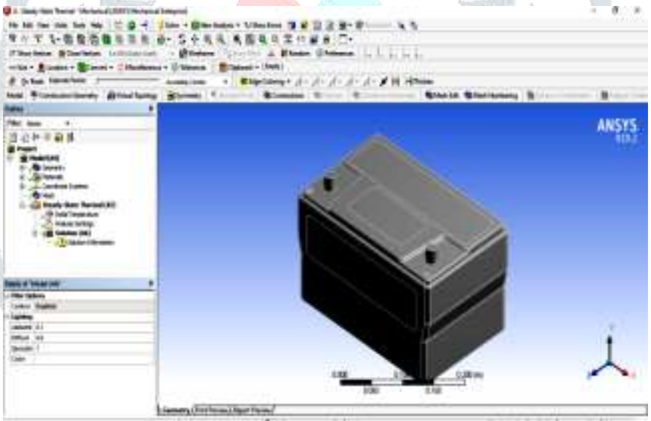

Figure 2: Model in Ansys workbench

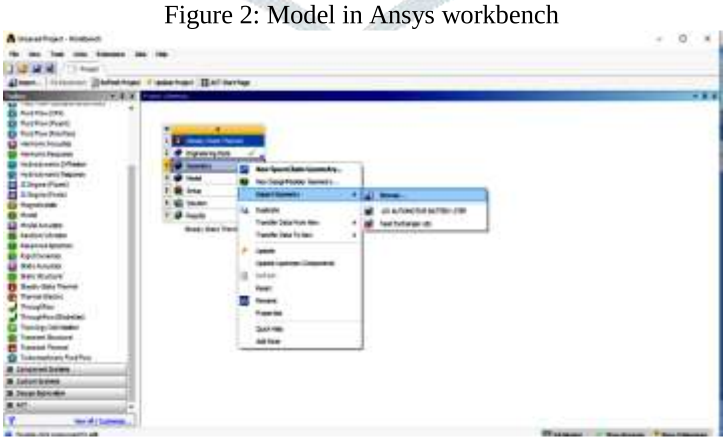

Figure 3: Import Geometry

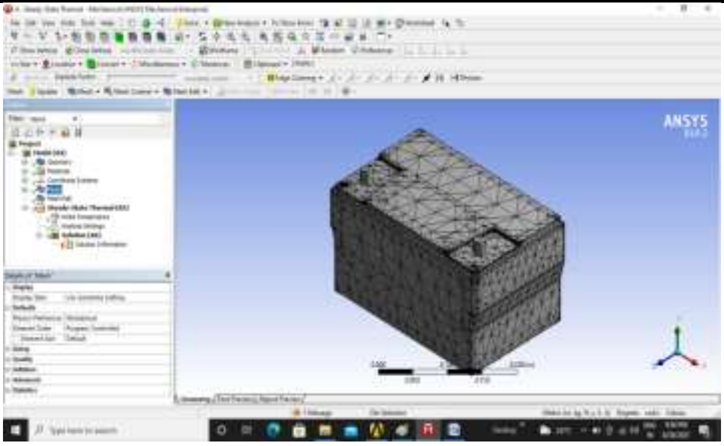

Figure 4: Apply mesh

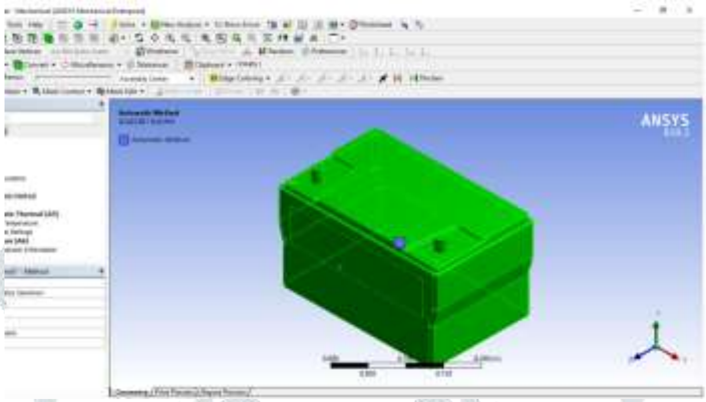

Figure 5: Selection of the geometry

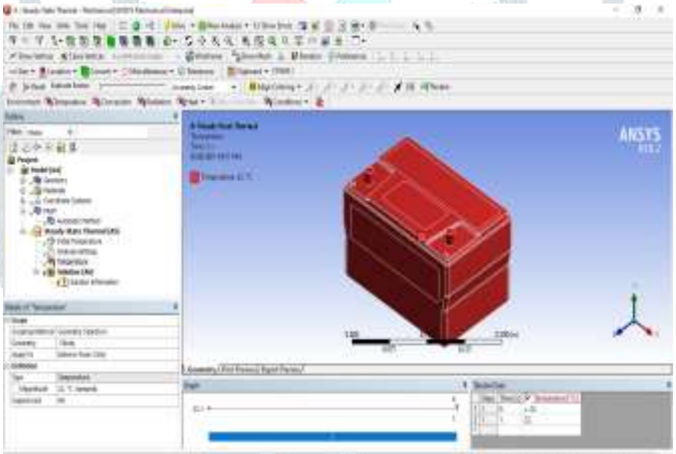

Figure 6: optimize temperature (22·C)

Details of "Mesh"	
Minimum Edge Length	2.54e-005 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	19504
Elements	11127

Figure 7: Details of Mesh

Table 2: Structural Steel > Constants

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

V. CONCLUSION

This research presents the design and thermal analysis of lithium ion battery for electrical/ hybrid vehicles application. Modified design of lithium ion battery with improved thermal performance is proposed. The analytical analysis and finite element method is presented in this work of thesis. The method developed in this thesis work can be used to analysis contact temperature and electricity for mechanical components. ANSYS workbench output is compared with the analytical method and alike results are comes with fair precision. In order to get the contact Strength Coefficient, Strength Exponent, Ductility Coefficient, Ductility Exponent, Cyclic Strength, Coefficient, Cyclic Strain Hardening. The mechanical components with or without the temperature influence, both analytical and ANSYS workbench must be used by the researchers. The following conclusions can be generally ascertained from this study work.

REFERENCES

[1]. M. Ehsani, Y. Gao, S.E. Gay, and A. Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, New York: CRC Press, 2005.

[2]. H.B. Meiwes, J. Drillkens, B. Lunz, J. Muennix, S. Rothgang, J. Kowal, and D.U. Sauer, "A review of current automotive battery technology and future prospects", Proc. of the Inst. of Mech. Engineers, Part D: Jr. of Auto. Engineering, 227(5), pp. 761–776, April 2013.

[3]. K. Young, C. Wang, L.Y. Wang, and K. Strunz, "Electric Vehicle Battery Technologies", in Electric Vehicle Integration into Modern Power Networks, R. García-Valle and J.A.P. Lopes (Ed), New York: Springer; 2013.

[4]. Y. Miao, P. Hynan, A.V. Jouanne, and A. Yokochi, "Current Li-Ion Battery Technologies in Electric Vehicles and Opportunities for Advancements", Energies 2019, 12, 1074, pp. 1-20, Mar 20, 2019.

[5]. J.M. Tarascon, and M. Armand, "Issues and challenges facing rechargeable lithium batteries", Nature, vol. 414, no. 6861, pp. 359-367, Nov. 2001.

[6]. "The Octagon Battery – What makes a Battery a Battery", available at https://batteryuniversity.com/learn/article/the_octagon_battery_what_makes_a_battery_a_battery Is Li-Ion the Solution for the Electric Vehicle? Available online: https://batteryuniversity.com/learn/

[7]. Guo, Z., and Z. Chen. 2015. "High-temperature capacity fading mechanism for LiFePO4=graphite soft-packed cell without Fe dissolution." J. Electroanal. Chem. 754 (Oct): 148–153. https://doi.org/10.1016/j.jelechem 2015.07.009.

[8]. Huo, Y. T., Z. H. Rao, and X. J. Liu. 2015. "Investigation of power battery thermal management by using mini-channel cold plate." Energy Convers. Manage. 89 (Jan): 387–395. https://doi.org/10.1016/j enconman.2014.10.015.

[9]. Hussain, A., C. Y. Tso, and C. Y. H. Chao. 2016. "Experimental investigation of a passive thermal management system for high-powered

[10]. Lithium ion batteries using nickel foam-paraffin composite." Energy 115 (Part 1): 209–218. https://doi.org/10.1016/j.energy.2016.09.008.

[11]. Ianniciello, L., P. H. Biwolé, and P. Achard. 2018. "Electric vehicles batteries thermal management systems employing phase change materials."

[12]. J. Power Sources 378 (Feb): 383–403. https://doi.org/10.1016/j .jpowsour.2017.12.071.

[13]. Jarrett, A., and I. Y. Kim. 2011. "Design optimization of electric vehicle battery cooling plates for thermal performance." J. Power Sources 196 (23): 10359–10368. https://doi.org/10.1016/j.jpowsour.2011.06090.

[14]. Jiaqiang, E., X. Zhao, and H. Liu. 2016. "Field synergy analysis for enhancing heat transfer capability of a novel narrow-tube closed oscillating heat pipe." Appl. Energy 175 (Apr): 218–228. https://doi.org/10 1016/j.apenergy.2016.05.028.

[15]. D.A. Ferreira, L.M.Z. Prados, D. Majuste, M.B. Mansur Hydrometallurgical separation of aluminium, cobalt, copper and lithium from spent Li-ion batteries.

[16]. R. C. Cope and Y. Podrazhansky, "The Art of Battery Charging", *14th Battery Conference on Applications and Advances*, pp. 233-235, 1999.

[17]. V. Srinivasan and C. Y. Wang, "Analysis of Electrochemical and Thermal Behavior of Li-Ion Cells", *Journal of The Electrochemical Society*, vol. 150, no. 1, pp. A98-A106, 2003.

[18]. A. A. Hussein and I. Batarseh, "State-of-charge estimation for a single Lithium battery cell using Extended Kalman Filter", *IEEE Power and Energy Society General Meeting*, pp. 1-5, 2011.

[19]. G. L. Plett, "Extended Kalman filtering for battery management systems of LiPB-based HEV battery packs: Part 3. State and parameter estimation", *Journal of Power sources*, vol. 134, no. 2, pp. 277-292, 2004.

[20]. H. He, R. Xiong, X. Zhang and F. Sun, "State-of-charge estimation of the lithium-ion battery using an adaptive extended Kalman filter based on an improved thevenin model", *IEEE Transactions on Vehicular Technology*, vol. 60, no. 4, pp. 1461-1469, 2011.