International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 07, ISSN No. 2455-2143, Pages 24-29
Published Online November 2025 in IJEAST (http://www.ijeast.com)

COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF BATTERY COOLING SYSTEM

Ajmeer Ali.A, Murugesh.S, Nitheesh Kumar.K, Sri Saran.V
Department Of Mechanical Engineering
Anjalai Ammal Mahalingam Engineering College
Kovilvenni, Tamil Nadu India.

Abstract— **Thermal management design for battery used in automobiles are very important in order to manage the thermal dissipated by operating components. This research aims at performing design optimization of a thermal management system for battery modules in modern vehicles. An active cooling systems is proposed where oil cooling system is used for battery modules. The causes of problem due to improper thermal management of battery is deployed to identify the potential failure modes and causes so that improvements can be made for battery modules. The design for the thermal management system were done with SOLIDWORKS. To maintain the temperature of battery helical passage and exterior flow passage is used, the radiator coolant oil is used as the fluid to conduct heat from battery during its passage time. The thermal management system for battery modules is simulated using ANSYS CFD software. Results from simulation were validated and have shown good agreement based on the data collected at various vehicle speeds.**

Keywords— **Battery Thermal Management, CFD Simulation, Active Cooling, Phase Change Material, Electric Vehicle Battery**

I. INTRODUCTION

Electric vehicles (EVs) are the most promising solution for a clean and green environment as the world is relying more on renewable energy sources and a battery is a better place to store the uniform energy from these sources. A power battery is the heart of electric vehicles and the basic challenge for EVs is to find a suitable energy storage device capable of supporting high mileage, fast charging, and efficient driving. Lithium-ion batteries (LIBs) are considered the most feasible power source for EVs due to their advantages Besides, the Li-ion battery consists of eco-friendly materials without harmful gassing problems and has of these cells is limited by the internal heat generation. Therefore, a battery thermal management batteries from the adverse effects caused by the rise in temperature a high level of safety. The performance, life, and safety of a Li-ion battery are highly influenced by storage or system (BTMS) is essential to prevent the operating temperature and environmental conditions. However, the performance and internal heat generation.

II. PROBLEM STATEMENT

Electric vehicles (EVs) rely on Li-ion batteries, which offers high Efficiency but suffer from overheating due to heat generation. High temperature impact battery performance, lifespan and safety making an effective Battery Thermal Management System(BTMS) essential. A well-designed BTMS prevents overheating, ensuring better efficiency and safety of EV batteries under varying operating conditions. Lithium-ion battery modules used in EVs, exposed to high thermal loads during operation. Input parameters include battery temperature. Optimized cooling performance measured in terms of temperature, pressure, and velocity distribution across battery modules. Improper thermal regulation leads to uneven temperature distribution, which reduces battery life, safety, and performance.
.

III. OBJECTIVE

To design, simulate, and validate a thermal management system for electric vehicle battery packs using oil cooling techniques, enhancing temperature control and system reliability. To evaluate the influence of design parameters such as fin geometry, flow rate, and coolant type on the cooling efficiency and temperature uniformity of the battery pack. Assess the temperature distribution within the battery modules. Identify and mitigate hotspots to ensure uniform cooling. Analyze the effectiveness of the helical passage and exterior flow passage. Propose design modifications to enhance heat transfer performance. Compare CFD simulation results with experimental or benchmark data. Ensure accurate predictions of coolant temperature, pressure drop, and battery temperature

IV. LITERATURE REVIEW

1. SIMULATION OF TEMPERATURE FIELD OF LITHIUM BATTERY PACK BASED ON COMPUTATIONAL FLUID DYNAMICS

Zhenpo Wang, Wentao Fan, Peng Liu

Unprecedented opportunities for the development of pure electric vehicle industry have been brought by constantly growing issues of energy crisis and environmental pollution. The performance of electric vehicles is decisively influenced by the battery pack, which is the only power source of pure electric vehicles. However, the efficiency of battery drops under the conditions of ultra-high, ultra-low, and uneven temperature distribution inside the battery pack. To improve the performance, reliability and safety of the lithium-ion battery pack, the negative effect of non-uniform heat dissipation should be alleviated. In this paper, the thermal model of the lithium-ion battery is described. A 3D battery pack model is built. Several structural factors that affect the heat dissipation, including the selection of the location and quantity of the battery pack outlet, the arrangement mode of cells, and the distance between cells and wall, are simulated by utilizing the finite element analysis (FEA) and discussed. According to the simulation result, the factors influencing the battery temperature field and the influence law is summarized.

2. FULL HYBRID ELECTRICAL VEHICLE BATTERY PACK SYSTEM DESIGN, CFD SIMULATION AND TESTING

Debashis Ghosh, Brian K. Schwemmin, Kimberley King, Douglas Zhu

CFD analysis was performed using the FLUENT software to design the thermal system for a hybrid vehicle battery pack. The battery pack contained multiple modular battery elements, called bricks, and the inlet and outlet bus bars that electrically connected the bricks into a series string. The simulated thermal system was comprised of the vehicle cabin, seat cavity, inlet plenum, battery pack, a downstream centrifugal fan, and the vehicle trunk. The fan was modeled using a multiple reference frame approach. A full system analysis was done for airflow and thermal performance optimization to ensure the most uniform cell temperatures under all operating conditions. The mesh for the full system was about 13 million cells run on a 6-node HP cluster. A baseline design was first analyzed for fluid-thermal performance. Subsequently, multiple design iterations were run to create uniform airflow among all the individual bricks while minimizing parasitic pressure drop. NVH issues were also addressed in the design by keeping the flow streamlined thereby minimizing flow induced turbulence. The prediction for system pressure drop and cell temperature correlated well with test data on an instrumented battery pack.

3. OPTIMIZATION FOR COOLING SYSTEM OF BATTERIES HAVING POROUS MATERIAL USING DESIGN OF EXPERIMENTS

Zhen-Zhe Li, Dong-JiXuan, Yong Li & Yun-De Shen

A hybrid power composed of fuel cell and batteries has become the reasonable strategy for hybrid electric vehicles. On the contrary, the produced heat by batteries can affect the total performance of hybrid electric vehicles significantly. In this paper, analysis methods and optimization strategy were constructed for obtaining the high performance cooling system for batteries having porous material. At first, a numerical method for obtaining the temperature distribution of battery pack including porous material was developed by using CFD technique. In the following step, the cooling systems for batteries with porous material or not were compared for showing the merit of the cooling system for batteries having porous material. Ultimately, an optimization strategy based on D-optimal DOE method was obtained through a real optimal design process. There was 13.3% reduction on the view of the root mean square temperature between batteries compared with the original cooling system for batteries as shown in the optimization result. The constructed analysis method and optimization strategy can be used to improve the performance of the cooling system for batteries, and these works have made the theoretical basis for simulation and optimization of the cooling system for batteries.

4. DESIGN OPTIMIZATION OF THERMAL MANAGEMENT SYSTEM FOR ELECTRIC VEHICLEUTILIZING CFD ANALYSIS, DFMEA AND CES

Noreffendy Tamaldin, Ahmad Kamal Mat Yamin, Mohd Fadzli Bin Abdollah, Hilmi Amiruddin, Mohd Azman Abdullah

Thermal management design for electric vehicles (EV) is very important in order to manage the thermal dissipated by operating components. This research aims at performing design optimization of a thermal management system for battery modules, controller and electric motor in EV. A combination of passive and active cooling systems is proposed where air cooled is used in battery modules, water cooling for controller and water jacket for electric motor. Design Failure Mode and Effect Analysis (DFMEA) method is deployed to identify the potential failure modes and causes so that improvements can be made for battery modules, controller and electric motor. The design for all of the components and the thermal management system were done with CATIA V5. The material selections process for the designs was based on the analysis using Cambridge Engineering Selector (CES EduPack). Final design was utilizing water cooled for electric motor and controller while using air cooled for battery modules. It was found that best material for electric motor and controller water jacket is with aluminum alloy 6060 while air cooled ducting using High Density Poly Ethylene (HDPE) and battery housing using Poly cyclohexylenedimethylene Terephthalate (PCT). The thermal management system for battery modules is simulated using ANSYS CFD software. Results from simulation were validated with manual calculation and have shown good agreement based on the data collected at various vehicle speeds.

5. ADVANCED BATTERY THERMAL MANAGEMENT FOR ELECTRICAL-DRIVE VEHICLES USING RECIPROCATING COOLING FLOW AND SPATIAL-RESOLUTION, LUMPED CAPACITANCE THERMAL MODEL

International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 07, ISSN No. 2455-2143, Pages 24-29
Published Online November 2025 in IJEAST (http://www.ijeast.com)

Rajib Mahamud
The thermal management of traction battery systems for electrical-drive vehicles directly affects vehicle dynamic performance, long-term durability and cost of the battery systems. The time efficient yet accurate computational model for the battery thermal management system is essential results showed that the reciprocating flow can reduce the cell temperature difference of the battery system by about 4°C (72 % reduction) and the maximum cell temperature by 1.5°C for a reciprocation period of $\tau = 120$ seconds as compared with the uni-directional flow case ($\tau = \infty$). Such temperature improvement attributes to the heat redistribution and disturbance of the boundary layers on the formed on the cells due to the periodic flow reversal. From the cell-level concern, the spatial-resolution, lumped-capacitance thermal models for cylindrical battery cells under high Biot number (Bi □ 0.1) conditions where the classical lumped-capacitance thermal model is inapplicable because of the significant temperature variation in the battery cells was presented in this analysis. The improved lumped-capacitance thermal models were formulated using first- and second-order Hermite integral approximations. For a validation of the results from the lumped-capacitance models, one-dimensional, transient analytical (exact) solutions using the Green function were obtained for the cylindrical Li-ion battery cells. It was found from the comparison of the results from the computational models that the spatial-resolution, lumped capacitance thermal models accurately predict the temperatures (core, skin and area-averaged) of the battery cell under various battery duty cycles for a wide range of the Biot numbers covering air cooling to liquid cooling conditions. The battery heat generation was approximated by uniform volumetric joule and reversible (entropic) losses to improve the performance, safety, and life time of the battery systems. In this analysis, the thermal management system is divided into two different perspectives: pack-level and cell level thermal management system. For the pack-level modeling, a new battery thermal management method using a reciprocating air flow for cylindrical Li-ion ($LiMn_2O_4/C$) cells was numerically analyzed using (i) a two-dimensional Computational Fluid Dynamics (CFD) model and (ii) a lumped-capacitance thermal model for battery cells and a flow network model. The results of the CFD model were validated with the experimental results of in-line tube-bank systems which approximates the battery cell arrangement considered for this study. The numerical

V. METHODOLOGY

Solid Works is a solid modeler, and utilizes a parametric feature-based approach to create models and assemblies. The software is written on Para solid-kernel.
Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allows them to capture design intent.

CREATING A PART AND DRAWING:
When Solid Works is first opened, you have to open a part, assembly or drawing. When a new part is opened, there is a blank work area on the right and a column on the left called the Feature Manager. In the Feature Manager, there are the three main planes listed – front, top and right. To begin a sketch, a plane to draw on must be selected. Right click on the desired plane and select the sketch icon in the fly-out menu. For the first sketch the view will rotate so that you are looking perpendicular to the plane you selected. The first feature sketched is called the base feature. Added on features are called boss or cut features. These add or subtract material to create the part. It is best to keep the geometry of each feature as simple as possible. Create a part with a large number of simple features rather than a few complex ones. Your work will be much easier to perform and less prone to errors in the long run.

FILE FORMAT:
Solid Works files use the Microsoft Structured Storage file format. This means that there are various files embedded within each SLDDRW (drawing files), SLDPRT (part files), SLDASM (assembly files) file, including preview bitmaps and metadata sub-files. Various third-party tools (see COM Structured Storage) can be used to extract these sub-files, although the sub files in many cases use proprietary binary file formats.

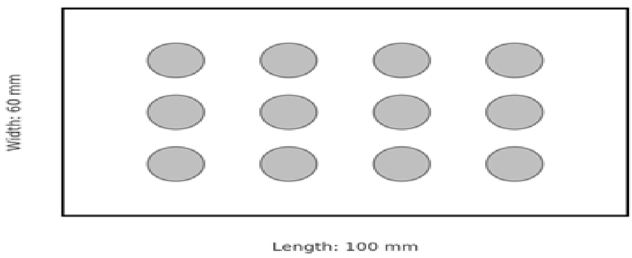
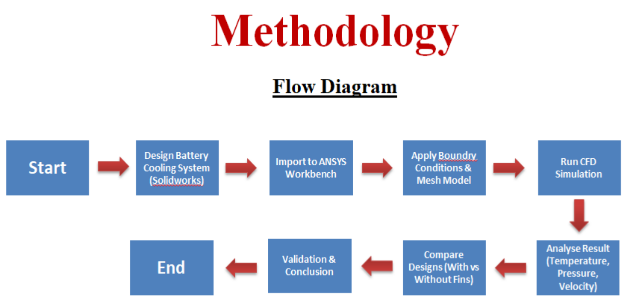


Fig 4.1 2D Diagram of Test Specimen



International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 07, ISSN No. 2455-2143, Pages 24-29
Published Online November 2025 in IJEAST (http://www.ijeast.com)

VI. INTRODUCTION TO SOLIDWORKS

Solid Works (stylized as SOLIDWORKS), is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) software program that runs on Microsoft Windows. The Solid Works is produced by the DASSAULT SYSTÈMES— a subsidiary of Dassault Systems, S. A. based in Velizy, France— since 1997.
Solid Works is currently used by over 2 million engineers and designers at more than 165,000 companies worldwide. In 2011–12, the fiscal revenue for Solid Works was reported $483 million.

CREATING A PART AND DRAWING:
When Solid Works is first opened, you have to open a part, assembly or drawing. When a new part is opened, there is a blank work area on the right and a column on the left called the Feature Manager. In the Feature Manager, there are the three main planes listed – front, top and right. To begin a sketch, a plane to draw on must be selected. Right click on the desired plane and select the sketch icon in the fly-out menu. For the first sketch the view will rotate so that you are looking perpendicular to the plane you selected.

COMMONLY USING TOOLS FOR MODELLING IN SOLIDWORKS:
1. Extrude
2. Extrude cut
3. Revolve
4. Revolve cut
5. Sweep
6. Swept cut
7. Fillet
8. Chamfer
9. Mirror

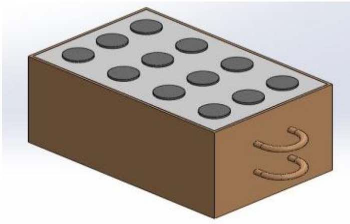


Fig 6.1 3D Diagram of Test Specimen

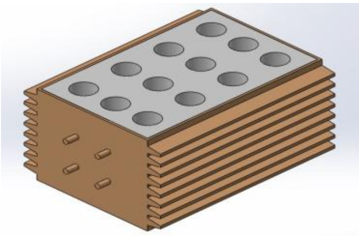


Fig 6.2 3D Diagram of Test Specimen

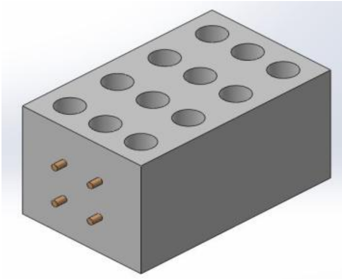


Fig 6.3 3D Diagram of Test Specimen

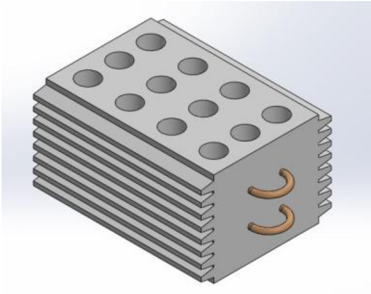


Fig 6.4 3D Diagram of Test Specimen

VII. ANSYS WORKBENCH

ANSYS Workbench combines the strength of our core simulation tools with the tools necessary to manage your projects. You will work with your ANSYS Workbench project on the main project workspace, called the Project tab. The project is driven by a schematic workflow, represented visually on a flowchart like diagram called the Project Schematic. To build an analysis, you add building blocks called systems to the Project Schematic; each system is a block of one or more components called cells, which represent the sequential steps necessary for the specific type of analysis. Once you have added your systems, you can link them together to share and/or transfer data between systems. From the cells in the Project Schematic, you can work with various ANSYS applications and analysis tasks. Some of these open in tabs within the Workbench environment, while others open independently in their own windows.
ANSYS applications allow you to specify parameters such as geometry parameters, material properties and boundary conditions. Parameters can be defined within the application and managed at the project level in the Workbench environment. To perform your analysis, you will work through the cells of each system in order typically from top to bottom defining inputs, specifying project parameters, running your simulation, and investigating the results. Workbench enables you to easily investigate design alternatives. You can modify any part of an analysis or vary one or more parameters, and then automatically update the project to see the effect of the change on the simulation result.

International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 07, ISSN No. 2455-2143, Pages 24-29
Published Online November 2025 in IJEAST (http://www.ijeast.com)

ANSYS WORKBENCH SYSTEMS

The systems available in the Project tab Toolbox are divided into the following categories:

• Analysis Systems

Complete systems with all the necessary component cells already defined and ready to be populated. For example, a Static Structural analysis system includes all the cells needed for the analysis, Engineering Data through Results.

• Component Systems

Component building blocks which represent only a subset of a complete analysis. For example, you can use a Geometry component system to define your geometry and then connect the component system to several downstream systems, so component system can then be connected to several downstream systems, so that the downstream systems share the same geometry source.

The Component Systems category also includes applications that open outside of ANSYS Workbench (rather than as a tab), allowing you to use Workbench to manage your analysis data and files. This can be useful for products such as Mechanical APDL, which uses numerous files during an analysis.

ANALYSIS SYSTEMS :

One way to start an analysis in ANSYS Workbench is to select an analysis system from the Toolbox. When you select one of these analysis types, the corresponding system will appear in the

Project Schematic, with all the necessary components of that type of analysis. Some analysis types offer different solvers, noted in parentheses. The features available can differ from one solver to another.

Available analysis systems include:

1. Design Assessment
2. Electric
3. Explicit Dynamics
4. Fluid Flow (CFX)
5. Fluid Flow (Fluent)
6. Fluid Flow (Poly flow)
7. Harmonic Response
8. Hydrodynamic Diffraction
9. Hydrodynamic Time Response

COMPUTATION FLUID DYNAMICS :

The development of modern computational fluid dynamics (CFD) began with the advent of the digital computer in the early 1950s. Finite difference methods (FDM) and finite element methods (FEM), which are the basic tools used in the solution of partial differential equations in general and CFD in particular, have different origins. In 1910, at the Royal Society of London, Richardson presented a paper on the first FDM solution for the stress analysis of a masonry dam. In contrast, the first FEM work was published in the Aeronautical Science Journal by Turner, Clough, Martin, and Topp for applications to aircraft stress analysis in 1956. Since then, both methods have been developed extensively in fluid dynamics, heat transfer, and related areas There is a growing evidence of benefits accruing from the combined knowledge of both FDM and FEM. Finite volume methods (FVM), because of their simple data structure, have become increasingly popular in recent years, their formulations being related to both FDM and FEM. The flow field-dependent variation (FDV) methods also point to close relationships between FDM and FEM. we are seeking to recognize such views and to pursue the advantage of studying FDM and FEM together on an equal footing. Historically, FDMs have dominated the CFD community. Simplicity in formulations and computations contributed to this trend. FEMs, on the other hand, are known to be more complicated in formulations and more time-consuming in computations. However, this is no longer the case in many of the recent developments in FEM applications. Many examples of superior performance of FEM have been demonstrated. Our ultimate goal is to be aware of all advantages and disadvantages of all available methods so that if and when supercomputers grow many fold in speed and memory storage, this knowledge will be an asset in determining the computational scheme capable of rendering the most accurate results, and not be limited by computer capacity. In the meantime, one may always be able to adjust his or her needs in choosing between suitable computational schemes and available computing resources. It is toward this flexibility and desire that this text is geared.

VIII. RESULT & DISCUSSION

The outlet temperature increased more effectively in the finned model, confirming better heat transfer from the battery pack..Slight improvements in maximum velocity and pressure were observed in the system with fins, enhancing fluid flow and cooling effectiveness. Reducing boundary distance between battery modules improved cooling, especially when battery spacing was small—highlighting its role in thermal consistency.

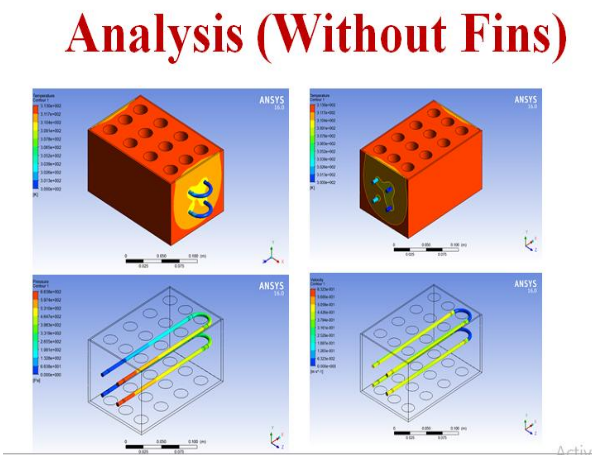


Fig 7.1 Analysis Without Fins

Analysis (With Fins)

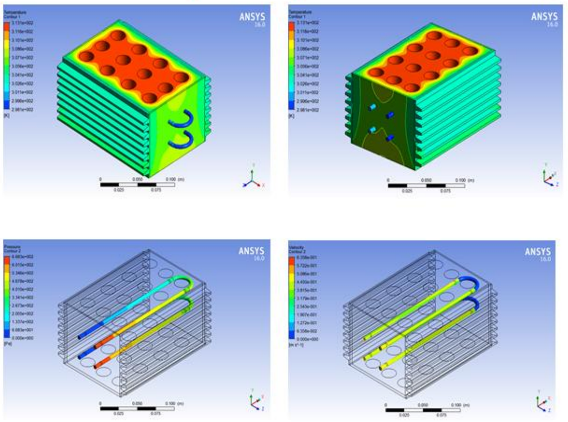


Fig 7.2 Analysis With Fins

Tabulation

Type of Thermal management system	Temperature (K)		Velocity (m/s)		Pressure (pa)	
	Inlet	Outlet	Min	Max	Min	Max
Without fins	298	300	0	6.32e-1	0	6.63e2
With fins	298	305	0	6.35e-1	0	6.68e2

Fig 7.3 Result With and Without Fins

IX. CONCLUSION

From the very beginning of the project, keys of designs were identified through information gathering and literature reviewing. Earlier conceptual designs were carried out through brainstorming method. During the design progresses, active cooling concepts were referred. The most goals - achieved designs were then chosen and proceed for drawing using SOLIDWORKS. For achieving thermal management two models have been finalized which are flow through chamber with and without fins. Both the systems are analyzed using ANSYS CFD. The exit temperatures from both results were compared and validated. With the increase of flow area, the cooling performance improves gradually. After exceeding a certain flow speed cannot improve battery pack cooling performance obviously. Boundary distance has great effect on the cooling performance. The cooling performance of pack rises gradually with the decrease of boundary distance; especially when the battery spacing is small, the effect of boundary distance on the battery consistency is more prominent. In terms of the arrangement of battery pack, staggered design is better than aligned design in cooling performance. Under the same air flow rate, increasing the number of inlet can improve the cooling ability of battery pack and staggered design for inlet can improve the consistency of battery temperature. In conclusion, there were still rooms for improvement in term of power consumptions and overall designs cost. The thermal management systems have been successfully designed and the objectives of the project were achieved.

X. REFERENCES

[1]. Bang, J. H., Kim, H. S., Lee, D. H., and Min, K., “Study on Operating Characteristics of Fuel Cell Powered Electric Vehicle with Different Air Feeding Systems,” Journal of Mechanical Science and Technology, Vol. 22, No. 8, pp. 1602–1611, 2008.

[2]. Pesaran, A. A., “Battery Thermal Models for Hybrid Vehicle Simulations,” Journal of Power Sources, Vol. 110, No. 2, pp. 377–382, 2002.

[3]. Sato, N. and Yagi, K., “Thermal Behavior Analysis of Nickel Metal Hydride Batteries for Electric Vehicles,” JSAE Review, Vol. 21, No. 2, pp. 205–211, 2000.

[4]. Wei, X. Z., Zou, G. N., and Sun, Z. C., “Modelling and Parameter Estimation of Li-Ion Battery in a Fuel Cell Vehicle,” Chinese Journal of Power Sources, Vol. 28, No. 10, pp. 605–608, 2004.

[5]. Belt, J. R., Ho, C. D., Miller, T. J., Habib, M. A., and Duong, T. Q., “The Effect of Temperature on Capacity and Power in Cycled Lithium Ion Batteries,” Journal of Power Sources, Vol. 142, No. 1, pp. 354–360, 2005.

[6]. Sabbah, R., Kizilel, R., Selman, J., and Al-Hallaj, S., “Active (Air- Cooled) vs. Passive (Phase Change Material) Thermal Management of High Power Lithium-Ion

[7]. Mills, A. and Al-Hallaj, S., “Simulation of Passive Thermal Management System for Lithium-Ion Battery Packs,” Journal of Power Sources, Vol. 141, No. 2, pp. 307–315, 2005.

[8]. Smith, K. and Wang, C. Y., “Power and Thermal Characterization of a Lithium-Ion Battery Pack for Hybrid-Electric Vehicles,” Journal of Power Sources, Vol. 160, No. 1, pp. 662–673, 2006.

[9]. Bajura, R. A. and Jones, E. H., “Flow Distribution Manifolds,” Journal of Fluids Engineering, Vol. 98, No. 4, pp. 654–665, 1976.

[10]. Choi, S. H., Shin, S., and Cho, Y. I., “The Effect of Area Ratio on the Flow Distribution in Liquid Cooling Module Manifolds for Electronic Packaging,” International Communications in Heat and Mass Transfer, Vol. 20, No. 2, pp. 221–234, 1993.