Title of the Project: BATTERY THERMAL MANAGEMENT USING HEAT PIPE INTEGRATED IMMERSION COOLING AND AIR CONDITIONING SYSTEM

Discipline under which the project is to be considered: Engineering & Technology

Name & Designation of the Principal Investigator: Dr. Murugan P C, Associate Professor, B.E., M.E., Ph.D.,

Name & Designation of the Co-PI: K Nithyanandhan, Assistant Professor, M.E,.(Ph.D.)

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Name of the Institution/Organization in which the project will be carried out:
Kongu Engineering College

Name of other Institution(s) Organization(s) involved in the Project:
Kumaraguru College of Technology, Coimbatore.
Bhannari Amman Institute of Technology, Sathyamangalam.
Karunya Institute of Technology and Sciences (Deemed University)

Duration of the Project (Maximum 2 years): 24 Months

Total Cost of the Project Proposal (details to be furnished in the prescribed format):

S. NO	Details	I year	II year	III year
A	Salaries & Wages Research fellow (@Rs.10000/pm)* OR Technical Assistant (@Rs.5000/pm)*	-	-	-
B C	i. Equipment (only project-specific minor equipment) ii. Details of major equipment/facilities expected to be available with the institution Consumables^ Chemicals/glasswares Fabrication / Service Testing Other Consumable Total	-	-	-
D	Travel	-	-	-
E	Total of A+B+C+D	-	-	-
F	Institutional overhead charge (Maximum of Rs.15000/per year)	-	-	-
G	Total Cost of Project	-	-	-

11 Abstract:

The thermal management of batteries is a crucial aspect to improve their performance, lifespan, and safety. In this research, the proposed method of battery thermal management system(BTMS) is heat pipe integrated immersion cooling with a Peltier cooling system to control battery temperature and maintain the uniform temperature over the entire battery pack. The study analyzes the performance and heat transfer characteristics of the heat pipe in an immersion cooling system by simulating it under actual operating conditions. A heat pipe thermal management system was employed in many applications but it is not so successful in BTMS due to the lack of experimentation. But in this system, it is proposed to use the heat pipe with a dielectric fluid medium in a lithium-ion battery pack which can able to absorb the heat from the battery cells and dissipates to the environment through the condenser section of a heat pipe at a higher rate. The modified design of the heat pipe condenser section and using acetone and acetone with Al_2O_3 and CuO nanofluids with different filling ratios in a heat pipe can able to control the temperature of the battery even under high charging and discharging conditions. Analytical results from the previous research suggest that the integrated system has better thermal stability but only limited experimental studies are done in the BTMS. The proposed hybrid thermal management system offers optimal thermal management in batteries and maintains thermal stability with extended battery life and performance. In conclusion, the proposed battery thermal management system can be utilized in many applications requiring high energy density and power density. Both heat pipes and immersed cooling systems offer practical and efficient thermal management solutions for lithium-ion batteries.

12 Details of the project proposal including the State-of-the art of the subject, the work already done in this area in India or elsewhere, and defining clearly the objectives and methodology and year-wise phasing of the project.

State of the Art:

With the growing demand for electric vehicles, there has been extensive research work done in the area of battery thermal management. One of the significant challenges faced in this area is to maintain the battery's temperature and achieve thermal stability within an acceptable limit to improve its lifespan and performance.

The use of batteries has become increasingly common in various applications, including electric vehicles, renewable energy systems, and consumer electronics. However, the performance and lifespan of batteries are strongly affected by their operating temperature, which can lead to safety hazards, decreased energy efficiency, and premature failure. The need for effective battery thermal management systems(BTMS) has thus emerged for the widespread adoption of battery-powered devices.

One approach for BTMS is the use of heat pipes integrated with immersion cooling and air conditioning systems. Heat pipes are passive thermal transfer devices that can efficiently dissipate heat from high-temperature sources to low-temperature sinks, using principles of heat conduction and evaporation/condensation. Immersion cooling involves submerging the battery cells in a dielectric liquid or coolant that enhances heat transfer and provides uniform temperature distribution. Air conditioning involves circulating air or other gases to cool down the coolant or the battery structure.

Recent studies have shown that the integration of heat pipes, immersion cooling, and air conditioning can achieve superior BTMS performance in terms of temperature control, thermal uniformity, energy efficiency, and safety. For example, a study by Chen et al. (2019) demonstrated that a heat pipe-integrated immersion cooling system can reduce the maximum temperature of a lithium-ion battery pack by up to 14°C and improve the thermal uniformity by up to 32% compared to a conventional air-cooled system. The use of a thermosiphon heat pipe with a nano-coated evaporator surface was found to enhance the heat transfer coefficient and reduce thermal resistance. Another study by Zhang et al. (2020) proposed a heat pipe-integrated air conditioning system that uses a phase-change material (PCM) as a secondary coolant to enhance energy storage and release capacity. The PCM can absorb or release latent heat during the melting-solidification process, thereby reducing the temperature swing of the battery pack and extending its lifespan. The simulation and experimental results showed that the combined system can achieve a cooling efficiency of 98% and maintain the battery temperature within a range of ± 1°C.

Despite these promising results, several challenges remain in the development and implementation of heat pipe-integrated immersion cooling and air conditioning systems for BTMS. These include the selection and optimization of heat pipe materials, the design and integration of complex thermal management systems, the cost-effective manufacture and maintenance of the components, and the compatibility and safety of the cooling fluids and battery chemistries.

Therefore, development is needed to advance the state of the art in BTMS using heat pipe-integrated immersion cooling and air conditioning systems and to address the practical challenges and limitations of the approach. The integration of other advanced technologies, such as artificial intelligence, data analytics, and control systems, can also enhance the performance, and safety of the BTMS systems in the future.

Work done in India/elsewhere:

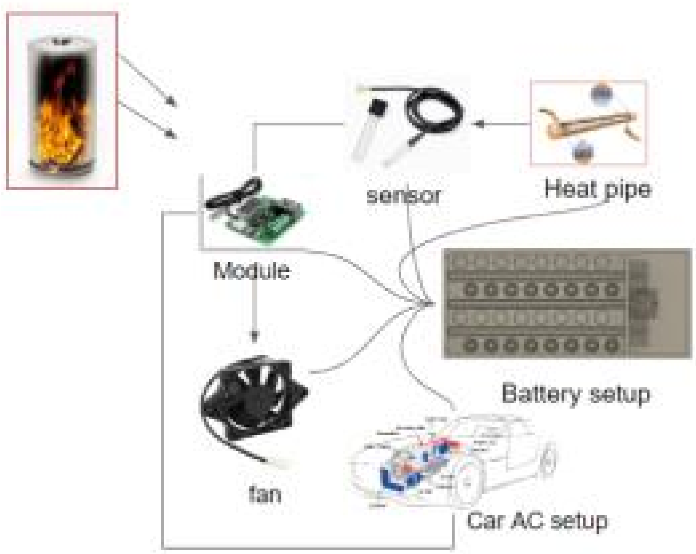
In India, several research institutes such as the Indian Institute of Technology (IITs) and private organizations such as Tata Motors, Mahindra Electric, and Ashok Leyland have been working on battery thermal management systems. Similarly, several international organizations and research institutions such as Tesla, General Motors, and the University of Michigan continuously work on this subject.

Objectives:

The objective of this proposed project is to develop a battery thermal management system using a heat pipe integrated immersion cooling and air conditioning system to manage and maintain the battery temperature within an optimal range.

Battery thermal management using heat pipe integrated immersion cooling and air conditioning system to improve the overall performance and lifespan of batteries, prevent thermal runaway and reduce the risk of fire and explosion, reduce energy consumption and operating costs, and increase the efficiency of charging and discharging. Develop a product to obtain a patent along with reputed companies. The objective of the battery thermal management system is to efficiently manage the temperature of the battery pack in order to optimize its performance, extend its lifespan and ensure safe operation. The system should be able to maintain the ideal temperature range of the battery cells to improve the efficiency and capacity of the batteries by reducing losses due to high temperatures and improving charge acceptance. It should also provide accurate monitoring and control of the battery temperature to prevent overcharging and overheating, which may lead to safety hazards and reduce battery life. The thermal management system must be designed to meet the specific requirements of different battery chemistries and sizes, taking into account the operating conditions and environmental factors. The system should be cost-effective, reliable, and easily integrated into various types of vehicles and energy storage systems.

The goal of the battery thermal management system is to provide a safe and efficient way to maximize the performance of battery systems and meet the growing demand for affordable and sustainable energy storage solutions.



Methodology:

To achieve the objective of the project, we will follow the following methodology:

- ➢ Define the performance requirements: The first step in developing a battery thermal management system is to define the required performance parameters, such as battery temperature range, efficiency, and safety.

- ➢ Conduct battery characterization: Conduct a comprehensive characterization of the battery under different operating conditions to determine the heat generation and cooling requirements.
- ➢ Develop a suitable thermal model: Develop an accurate model of the battery pack and its thermal characteristics. The thermal model should take into account factors like heat transfer coefficient, thermal conductivity, and specific heat capacity of the batteries.
- ➢ Determine the thermal management approach: Decide on the most suitable thermal management approach depending on the application. Some of the common thermal management methods include liquid cooling, air cooling, phase change material (PCM), and heat pipes.
- ➢ Develop the control algorithm: Design and develop a control algorithm that will manage the temperature of the batteries within the required range. The control algorithm should take into account the heat generation, cooling capacity, and battery charging and discharging rates.
- ➢ Test the thermal management system: Once the complete thermal management system is developed, it should be tested under various operating conditions to validate its performance. The testing should include environmental factors such as ambient temperature changes, workload changes, and possible battery faults.
- ➢ Optimize the thermal management system: Based on the results of testing and validation, the thermal management system should be optimized to improve efficiency, reliability, and safety.

Year 1:

1. Design and fabrication of the battery cooling system.
2. Establish a battery pack model for the cooling system.
3. Design and construct an experimental setup.
4. Conduct the testing to validate the model.
5. Analyze the collected data and validate the performance of the battery thermal management system.

Year 2:

6. Conduct experimental testing to refine the model.
7. Integrate the battery thermal management system with an electric vehicle.
8. Conduct real-world vehicle testing.
9. Make necessary modifications and improvements to the battery cooling system.
10. Demonstrate the system's reliability and performance.

Year-wise phasing of the project:

Year 1:

1. Design and fabrication of the battery cooling system - 4 months

2. Establish a numerical model for the cooling system - 2 months

3. Design and construct experimental setup - 3 months

4. Conduct experimental testing to refine the numerical model - 3 months

Year 2:

6. Integrate the battery thermal management system with an electric vehicle - 3 months

7. Conduct real-world vehicle testing - 2 months

8. Analyze the collected data and validate the performance of the battery thermal management system - 3 months

9. Make necessary modifications and improvements to the battery cooling system - 2 months

10. Demonstrate the system's reliability and performance - 2 months

Conclusion:

The proposed project aims to develop an efficient thermal management system for electric vehicle batteries using a heat pipe-integrated immersion cooling and air conditioning system. The project will provide significant insights into battery temperature management and improve the battery's lifespan and vehicle performance. The proposed year-wise phasing of the project will ensure the smooth progress of the project and successful completion within the specific timeline.

13 Brief bio-data of the Investigator(s)

Name	Dr. Murugan P C
Designation	Associate Professor
Qualification	B.E., M.E., Ph.D.,
Supervisor Recognition id	Anna University / 3520010
Area of Specialization	Alternate Fuels, Thermal Management Systems, Renewable Energy, CFD,
Date of Joining KEC	05-06-2017
Experience in (Years):	10.2 Years
Number of Papers Published:	35
Number of Papers Presented:	10

14 Facilities available at the Institution/ organization to carry out the project

- ULRASONICATOR
- TEMPERATURE MEASURING INSTRUMENT
- CFD ANALYSIS SOFTWARE WITH HYPER COMPUTERS

15 Social relevance and usefulness of the project:

The battery thermal management system using a heat pipe integrated immersion cooling and air conditioning system is a highly relevant project as it is directly linked to the growth of electric vehicles. The current generation of lithium-ion batteries used in electric vehicles is vulnerable to high temperatures, which can cause a reduction in their lifespan and overall efficiency. Implementing an efficient battery thermal management solution can significantly improve the vehicle's performance and extend the battery's lifespan. This solution enables the sustainable use of electric vehicles and shifts the global trend towards eco-friendly transportation. This project emphasizes an efficient thermal management system, which can improve the performance and lifespan of EV batteries and make them a viable alternative to traditional gas-powered vehicles. It is a socially relevant and useful innovation that can have a long-term impact on reducing greenhouse emissions, promoting clean energy, and economic development in the transportation sector.