Design of Electric Vehicle Battery Cooling System with Phase Change Material (PCM)

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Abstract. The development of electric vehicles is still hampered by excessive heat that occurs in electric vehicle batteries. Battery Thermal Management Systems (BTMS) are needed for thermal management that occurs in electric vehicle batteries. BTMS can reduce the negative impact of temperature on batteries. Various studies have been carried out to overcome overheating in electric vehicle batteries. One way that can be done is by using an electric vehicle battery cooling system. Utilizing Phase Change Material (PCM) as a cooling medium for electric vehicle batteries is one alternative that can be done. Many things can influence the effectiveness of battery cooling, including PCM material, PCM position relative to the battery, PCM shape, PCM dimensions, and so on. Of the several PCM materials being developed, paraffin material is a potential PCM material candidate for development, but this material has low thermal conductivity. The addition of other elements to paraffin can increase the thermal conductivity of PCM. In this research, an electric vehicle battery cooling system was designed using paraffin and TiO_2 as PCM, with the hope of providing an effective battery cooling effect. From the research results, it is known that using PCM as a battery cooling medium can provide a better reduction in battery temperature compared to not using PCM cooling, and the addition of TiO_2 as PCM to paraffin can provide better cooling compared to using pure PCM.

Keywords: Electric vehicle battery, Phase change material, Cooling system.

1 Introduction

The development of electric vehicles is still constrained by the occurrence of *overheating* in electric vehicle batteries, which is caused by battery performance. Overheating of batteries also has an impact on the electrochemical reactions that occur inside the cell, which can cause extra exothermic reactions and can cause a sudden rise in temperature resulting in an explosion [1]. The temperature of the battery should be kept in the range of 15-40◦C to avail its maximum effectiveness [2]–[4]. Various studies have been conducted to overcome the occurrence of *overheating* in electric vehicle batteries. [5] conducted a performance study of beeswax phase change materials, RT 44 and heat pipes as passive battery cooling systems for electric vehicles. From the results of his research, the use of *heatpipes* can reduce battery temperature by 26.62 °C at a heat load of 60 W, compared to a casing without a passive cooling system. [6] PCM composites provide a better heat release and temperature equalization effect on the battery compared to air cooling systems or pure PCM.

Various Phase Change Material (PCM) materials are tried to be developed for cooling electric vehicle batteries such as the use of paraffin, copper foam, SiO_2, graphite, TiO_2 and other material composites. Nanotechnology has also been tried to be researched by [7] about investigating the performance of finned heat sinks with nano-level phase change materials (NePCM) where a small percentage of nanoparticles (2%) are added, the performance of heat sinks can be improved until the PCM melts completely. An increase in the percentage of nano particles, can cause a decrease in the performance of heat zinc. The addition of 2% aluminum oxide nanoparticles can produce better heat zing performance compared to the case of adding equal percentage copper oxide. [8] prepare an expanded paraffin/graphite composite PCM, which has a large thermal storage capacity and high thermal conductivity. [9] developing paraffin/diatomite composite materials synthesized as PCM, test results show paraffin/diatomite composite materials as PCMs have good thermal energy storage capacity. [10]Utilizing TiO_2 as a PCM material by mixing TiO_2 in n-octadecane with infiltration under vacuum conditions. The results obtained by adding TiO_2 to n-octadecane can increase the thermal conductivity of PCM composites by 138%. [11] The addition of graphite and carbon foam to paraffin wax improves thermal properties and prevents leakage of molten paraffin maintaining stable thermal performance. Of the several PCM materials developed, paraffin material is a candidate for PCM material that has great potential to be developed, but this material has low thermal conductivity. The addition of other elements to paraffin as PCM is also widely studied such as the addition of SiO_2, graphite, nickel and others. In this study, we will try to design an electric vehicle battery cooling system by utilizing paraffin and nano TiO_2 materials as PCM and adjust the location of the PCM on the sidelines of the battery, in the hope that it can provide an effective battery cooling effect.

2 State of The Art

Battery Thermal Management System (BTMS) is a cooling system that is applied to reduce the temperature that occurs in the battery. In general, there are du events in BTMS, namely internal BTMS and external BTMS. Internal BTMS is a method of reducing heat generation in batteries by modifying the interior while external BTMS is an external thermal management system for heat dissipation in battery cells [12]. The utilization of copper foam composite material combined with paraffin can improve thermal management performance in electric vehicle batteries compared to cooling without PCM [13]. The utilization of paraffin and graphene expened-based PCM can improve the thermal conductivity and latent heat of the PCM material thereby improving the thermal management of the battery [14]. The variation of heat zing used as a cooling medium for electronic components affects cooling performance, where the use of PCM in heat zing provides a better cooling impact compared to heat zing without PCM. The thickness and number of pins on the heat zing also have an impact on cooling performance [15]. PCM material with liquid metal has a greater temperature reduction impact on heat zing than 1-octadecanol organic PCM aerial PVM. Judging by the protection time, liquid metal has twice as long protection as 1-octadecanol.

3 Method

3.1 Experiment Setup and Procedure

Starting from the existing problem, namely overheating of electric vehicle batteries caused by battery performance, one alternative that can be done is to provide a cooling system on the battery with a passive cooling method in the form of PCM. Several studies have already been conducted in the development of PCM as thermal management of electric vehicle batteries. Composite materials are possible PCM candidates to be developed. In this study, TiO_2 combined with paraffin as PCM material was tried. In mixing this material, which is used as the basic material of PCM is paraffin by providing a TiO_2 concentration of 1% - 5%, this percentage is a percentage that has a significant impact on changes in the thermal characteristics of composite materials based on the results of related studies that have been previously studied.

3.2 Model and Design

This research was designed using an experimental method, where 1 battery module equipped with a passive cooling system in the form of a box that gives the PCM (paraffin + TiO_2) which is used to absorb heat that occurs in the battery due to the work of the battery used to drive the motor. The temperature that occurs in the battery is measured with a type K thermocouple which is placed at 16 points in the battery and can be observed through loger data. Data can be monitored via a data loger connected by thermocouple to the battery. Data retrieval is carried out on battery performance without a cooling system and with a cooling system. More details can be seen in figure 1.

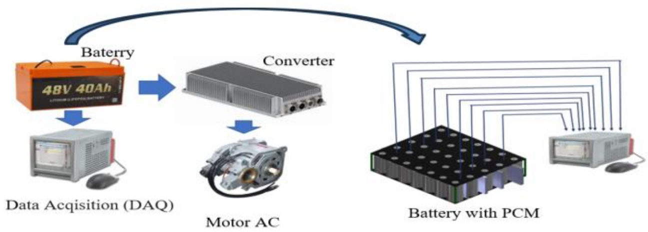

Fig. 1. Research Design

3.3 Research Variables

The variables of this study are in the form of independent variables and dependent variables. The independent variables in this study were PCM material and composition of paraffin and TiO_2 mixture. The dependent variable is the temperature that occurs in the battery.

3.4 Research Procedure

The study began by making a mixture of paraffin with TiO_2 with several mixture compositions. The composition of the mixture will be made with the composition; Paraffin 100%; Paraffin 95 % and TiO_2 5%; Paraffin 97 %, TiO_2 3%; Paraffin 98 %, TiO_2 2% .

The mixture will be mixed in liquid conditions using an ultrasonic device and then allowed to stand at room temperature and tested for material characteristics in each mixture formula. Each mixed formula will also be printed to make electric vehicle battery casing models. The resulting PCM mold is placed in between the battery as a cooling medium as in Figure 1. The temperature data on the battery is observed when the battery is provided with a cooling system in the form of PCM and without PCM. At the battery position, a cooling system in the form of PCM is provided, data is observed on several variations of the PCM mixture.

4 Result

4.1 Battery Temperature Without Cooling and with Cooling from Multiple PCM Materials

The utilization of PCM as a battery coolant has a significant impact on the cooling of electric vehicle batteries. From the results of the conducted research, the temperature of electric vehicle batteries with PCM cooling and without PCM cooling can be observed in Figure 2.

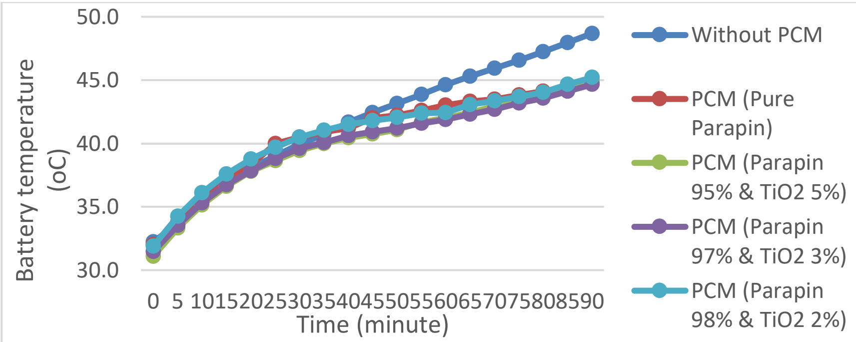

Fig. 2. Battery Temperature Graph Without Cooling and with Cooling from Multiple Refrigerant Materials

As seen in Figure 2, the battery temperature without cooling continues to increase from 0 minutes to 90 minutes, with the rate of temperature increase being higher compared to the battery temperature with PCM cooling. Starting at 40 minutes, the battery temperature without cooling remains higher than the battery temperature with PCM cooling. At the 90-minute mark, the temperature of the battery without cooling reaches 48.7°C.

When viewed from several PCM coolants, it is evident that battery cooling with PCM material consisting of 97% paraffin and 3% TiO_2 exhibits the lowest battery temperature and shares the same characteristics as the material of 95% paraffin and 5% TiO_2. Battery cooling with pure paraffin material (100% paraffin) results in the highest battery temperature, noticeable starting at 25 minutes. The addition of TiO_2 to paraffin can have an impact on slowing down the rate of battery temperature increase. This is caused by the addition of TiO_2 to the battery can enhance thermal conductivity of the material, thereby accelerating the heat absorption process from the battery to the PCM.

4.2 Change in Battery Temperature Per 5 Minutes Between Uncooled Batteries and Batteries Provided Cooling in the Form of Pure PCM

The temperature change of the battery in the initial minutes does not yet show a significant difference between the battery without cooling and the battery with cooling using pure PCM. From the 30th to the 90th minute, the battery with PCM cooling exhibits a lower rate of temperature increase compared to the non-cooled battery. This phenomenon occurs because after 30 minutes, the battery temperature reaches 40.5°C, causing the PCM used as the cooling medium to undergo a phase change. As a result, the concept of phase change cooling begins to operate, leading to a reduced rate of temperature increase in the battery. This is due to the heat energy generated by the battery being absorbed by the PCM for the phase change process. Further details are presented in Figure 3.

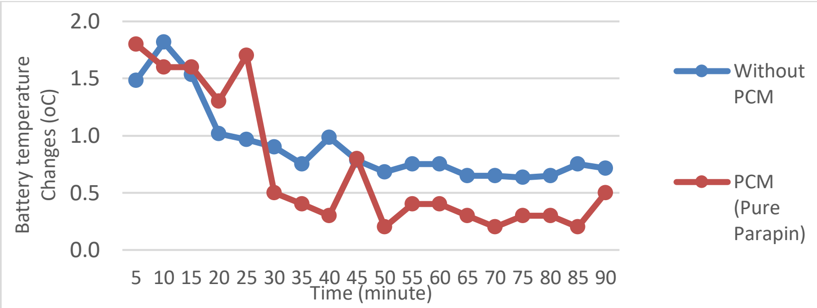

Fig. 3. Graphic of Battery Temperature Change Per 5 Minutes Between Uncooled Batteries and Batteries Provided Cooling in the Form of Pure PCM.

4.3 Change in Battery Temperature Per 5 Minutes Between Uncooled Battery and Battery Cooled in the Form of PCM Composite

From Figure 4, it can be observed that the temperature changes in 5-minute intervals during the observation period show no significant difference between the non-cooled battery and the battery cooled with a PCM composite in the early minutes up to the 25th minute. After 25 minutes, the rate of temperature in the battery using the PCM composite cooling is lower than that of the non-cooled battery. Among the various PCM composites used, they exhibit a similar heat-absorption capability from the battery, and their characteristics are quite stable. However, at the 60th and 65th-minute marks, the PCM composite consisting of a mixture of 98% paraffin and 2% TiO_2 shows less stable temperature changes. Therefore, from Figure 4, it can be observed that PCM composites with a mixture of 97% paraffin and 3% TiO_2, as well as a mixture of 95% paraffin and 5% TiO_2, demonstrate stability in dampening the temperature increase that occurs in the battery.

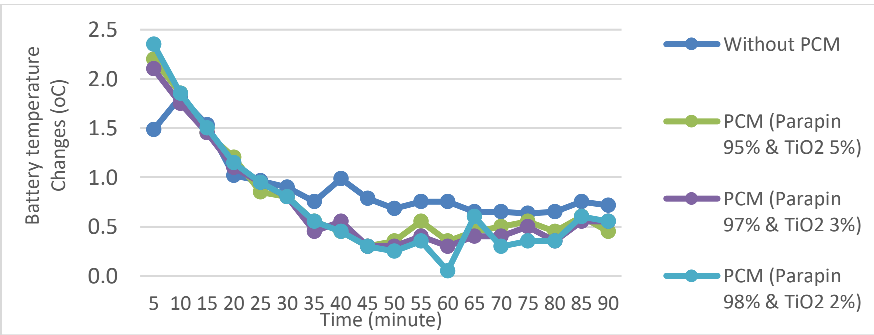

Fig. 4. Graphic of Battery Temperature Changes Every 5 Minutes Between Non-Cooled Battery and Battery Cooled with PCM Composite Cooling

5 Conclusion

From the result of conducted research, the following conclusions can be showed:

1. The utilization of PCM as a battery cooling medium can provide better battery temperature reduction compared to not using PCM cooling.
2. The addition of TiO_2 to paraffin as a PCM material can result in a faster decrease in battery temperature compared to pure PCM.
3. The addition of 3% TiO_2 can lead to a faster decrease in battery temperature compared to the addition of 5% and 2% TiO_2 in paraffin.
4. The addition of 3% and 5% TiO_2 to paraffin can more effectively mitigate the rate of battery temperature increase compared to the addition of 2% TiO_2 in paraffin and pure paraffin.

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