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Review of the Most Recent Literature on the Lithium-ion Polymer Battery for Electric Car

Rhenita G. L. Heng[1], Zuradzman M Razlan[2]
[1,2]Centre of Excellence for Unmanned Aerial System, University Malaysia Perlis (UniMAP), Kangar, Perlis, MALAYSIA
[1]rhenita.heng86@gmail.com

***Abstract*— The lithium-ion polymer battery is rapidly developing as the preferred electrical energy storage technology and generally used in portable electronics. Recently this technology has attracted worldwide attention, especially in the automobile sector. It is well suitable for fully electric cars to replace the current existing fossil fuel-powered cars. It also offers higher energy density by weight of all the commercial rechargeable battery technologies, with high operating voltage, high cycle life characteristics, and environmentally friendly in order to, improve the global warming problem by reducing the usage of combustion engine powered by fossil fuel and reduced the releasing amount of carbon dioxide to the atmosphere. The aim of this analysis is to improve the COP of an electric car lithium-ion polymer battery technically by studying the efficiency of the battery in various ambient temperature. Specific attention is paid concerning to the effects of temperature in the lithium-ion polymer battery for the electric car. However, this battery has not been widely marketed commercially in these types of cars yet due to manufacturing cost, safety, low temperature performance, which are all challenges connected to the battery thermal management system (BMTS). Therefore, an analysis and experiments of the literature reviews that related to the lithium-ion polymer battery for the electric car is presented and discussed.**

***Keywords*—Lithium-ion polymer battery, electric car, battery technology, battery thermal management system, temperature**

I. INTRODUCTION

Today, the world of technology is really important to the human. It offers something that giving comfort to the human lives in a better way. The electric car may present the best near term solution for the transportation sector to improve the global warming problem [1] by reducing the usage of combustion engine powered by fossil fuel and to reduce releasing the amount of carbon dioxide to the atmosphere.

Rechargeable lithium-ion polymer battery is well suitable for this car because they have high specific energy and energy density to other cell chemistries [2]. Yet, the electrochemical performance of the lithium-ion polymer battery was controlled by the operating temperature.

Thus, an efficient of Battery Thermal Management System (BTMS) is important for ideal performance in high temperature and high discharge application in order to keep the average battery system temperature in the range from 20^{o}C to 45^{o}C [3] and the optimum temperature is 45^{o}C in lithium-ion polymer operates a range (-30^{o}C to 60^{o}C). Experimental and simulation for the electric car battery pack by using the air cooling system. The result shows that when the discharge rate is high the temperature increased can be increased over 6^{o}C which is dangerous and can led to thermal runaway if exceed 80^{o}C. Therefore, the method proposed for battery thermal management system (BTMS) is active liquid cooling and heating that can be more operative for long-term use and increased the battery performance life [4]. The purpose of this paper is to review an analysis and experiments of the literature which related to the lithium-ion polymer battery for the electric car.

II. LITERATURE REVIEW

A. Electric Car

According to during the early centuries, the battery was powered for the first vehicles [5] and an electric motor were both railway locomotives was patented in 1847 by Moses Farmer. In the nineteenth century, William Morrison's design with a capacity for passenger is often considered the first real and practical electric car. In the early 1990s, it had lots of advantages over their competitors when the many Motor Vehicle Company starts building their own electric car. Professor William Edward Ayrton and John Perry were distinguished the First electric car in England.

The design of current electric cars is very different from conversion vehicles. An electric car uses one or more electric motor or traction motor for impulsion. There are three main types of electric cars exist and those they are straightly powered from an external power station, powered electricity that is stored in an external power source and powered by an on board electric generator [6].

Today car operates in extended operating temperatures. In fact, upcoming electric car would also disgust to function in both cold and hot climates [7].

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Thus the performance of the electric car must be upgraded in order to bit the market place. The performance and life cycle costs of electric cars inherently depended on battery power. Battery packs performance directly affects the all electric (zero-emission) [8][9] range, power for acceleration, fuel economic system, and charge acceptance during energy recovery from regenerative braking. Since the cost of the battery pack, durability, and the battery life cycle it may affect the cost and reliability of the electric cars [10], hence any parameter affected must be optimized.

B. Electric car Battery

Electric car battery is an important role in electric car to keep going on the road, thus the electric car battery pack needs to be secure from damage because of uneven temperature [11]. Depending on the electrochemical used in battery, the optimum range is different, but the ideal optimum temperature of electric car battery is 45°C in order to keep the performance and life for the battery [12]. Therefore, this research will investigate on the thermal management strategy [13][14] for the electric car battery pack. In general, higher temperatures increased the battery's performance due to the increased electrochemical reaction, but decreased the battery's lifetime because elevated temperatures increased corrosion. Another imperative impact of a battery pack's operating temperature is the electrical balance between modules in the pack. Battery pack performance depended on the performance of single modules. If when the modules and cells in the pack are at different temperatures, then each module will be charged or discharged slightly different on each cycle [15]. After several cycles, modules in the pack will become unstable, reducing the pack's performance.

C. Lithium-ion Battery

In the early 1990s, the rechargeable lithium-ion battery has come onto the market. This battery has greatly increased energy density in comparison with other rechargeable batteries. Lithium-ion battery is the third type most likely to be commercialized for electric car application [16][17]. This is because lithium has the highest negative potential and lowest atomic weight. Electrical energy is obtained from the combination of the lithium, carbon and the lithium metal oxide, however the lithium metal itself is highly reactive with air and liquid electrolytes. Moreover, lithium-ion battery can provide better performance [18] in team of acceleration and range for electric cars. This will present as the advantage of lithium-ion battery performance in order to compete the market place.

The lithium-ion battery has an outstanding potential for long life. This is because the operating temperature of this battery is wide from -20°C to 60°C. This battery takes around two to three hours to recharge. Besides, the important point for lithium-ion battery is an accurate control of voltage [19] needed when charging to ensure that overcharging does not occur. This is because the charging system must be capable with the battery management system in order to protect the battery from damage or explode. In addition, lithium-ion battery is more environmentally friendly compared to NiMH battery.

Furthermore the lithium-ion battery has considerable weight compared to other battery system, thus this battery is highly attractive candidate for future electric car. This is because lithium-ion battery allows for twice or more batteries used in electric car therefore it automatically will double the amount of energy storage and in the same way increased the vehicle's range and performance for better production. There are few electric cars is currently using the lithium-ion battery system based and, for instance, it was the Ford Escape hybrid [5] that has been produced in electric version around 2005.

D. Lithium-ion Polymer Batery

Through using rechargeable lithium-ion polymer battery able to reduce the greenhouse effect caused by emission of CO_2 [20] has been found by the automobile manufacturer. Thus, lithium-ion polymer battery is already replacing nickel-metal hydride (NiMH) batteries for portable devices such as notebook computers, tablets, smart phones and so on in the electronic manufactures [21]. Lithium-ion polymer battery also potentially have a much higher energy density compared to other battery technologies. Development of next-generation battery technologies by battery developers in Lithium Battery Energy Storage Technology Research Association (LIBES) [15] including lithium-ion polymer battery technology. The objective of the their research and development of lithium-ion polymer battery technology is to develop the solid-state lithium polymer battery using the carbon material as the anode.

E. Thermal Runway

Based on these three batteries used for electric car, the lithium ion battery is very sensitive the temperature [14]. This has been true for battery power cycling mode as well as in storage conditions. Therefore, it is necessary to manage the thermal behavior of the battery in electric car in order to optimize the energy balance [3] of the whole system and ensure that it operates within a safety range.

Moreover, thermal factors are likely to be useful for developing a strategy to prolong the battery pack lifetime. In addition to the thermal runaway and safety issues [14], such as overcharge, short circuits, and other extreme working conditions, it is very necessary to focus on the thermal behavior of the batteries, including the heat generating rate, under normal operating conditions. It will be very helpful for improving the efficiency of the cooling system [22][23][21], and maintaining the optimal battery performance.

Avoiding the beginning of thermal runaway is a very obtainable goal with proper battery maintenance program. Therefore the only way to efficiently prevent thermal runaway is to have some sort of full-time monitoring system. Without monitoring, the effort required to examine all possible scenarios is very difficult [24][25]. Hence, as a part of a successful maintenance program, have such as voltage and temperature monitoring can prevent the onset of thermal runaway and various other failure modes.

F. Air Distribution

There are two methods for distributing air to a pack for cooling and heating the batteries [3][4]. The first method is series cooling, where air pass in from one end of the pack and leaves from the other, exposing the equal quantity of air to several modules. The second method is parallel cooling. This method showed where the same total air flow rate is split into equal portions, and every portion flows over a single module. Besides that, depending on the size and geometry of the modular battery thermal management system can be applied in series-parallel combination or it could be configured. The parallel airflow provided a more even temperature distribution among the modules in the pack. However, in the series configuration is exposed to a higher air flow and the temperature is lower and reach steady faster. The minimum of temperature by using series air flow is 40°C compared to parallel air flow which is 46°C. However, regarding to the temperature variation ($T_{max} - T_{min}$) [4]the parallel cooling system showed the best temperature uniformly.

As to prove the calculation is shown below:

a. *Series*

Temperature Variation= T_{max} - T_{min}
Temperature Variation= 58°C - 40°C
Temperature Variation= 18°C

b. *Parallel*

Temperature Variation= T_{max} - T_{min}
Temperature Variation= 54°C - 46°C
Temperature Variation= 8°C

Therefore the pure parallel air distribution or even temperature distribution is better to be used for designing the cooling or heating system for an electric car to large battery pack.

G. Battery Thermal Management

The components and configuration of the battery thermal management system are determined by the method of the battery thermal management. Thermal management methods of electric cars such as active cooling versus passive cooling, air cooling versus liquid cooling, cooling and heating versus cooling only systems and the relative need of thermal management for lithium-ion battery [26]. The choice of heat transfer medium has major impact on the performance of the battery thermal management system. It could be air, liquid, phase change material (PCM) or any combination. By knowing, the heat transfer with liquid could be achieved either through indirect contact (jacket around a battery) or direct contact which is the battery pack is submerged in dielectric fluid or placed the battery pack directly to the cooled or heated plate (heat sink). Indirect contact usually used water or glycol as a heat transfer, however, if the system is designed as direct contact, the liquid must be dialectic such as mineral oil or silicon based in order to avoid ant electrical shorts. In fact, between direct and indirect liquid heating and cooling system, direct system can provide more effectiveness in transferring heat. It also could cost more for liquid based, however the indirect liquid system is easier to handle than direct liquid cooling.

Furthermore, few of the early electric car is also used passive ambient air cooling [25]. The ambient air must be at moderate temperature between 10° C to 35° C for battery thermal management system (BTMS) works or otherwise the battery pack can suffer in very hot and very cold condition as this system still considered as a passive system. Outside of this, the active components such as evaporators, heating core, heating the engine coolant, or fuel fired electricity are required. Therefore, as concluded, the thermal management system for battery pack should be selected based on the thermal requirement for battery type, location and climates [13].

III. REVIEW OF RELATED WORK

Al-Hallaj & Selman reported that lithium-ion battery module and battery pack by using thermal management system is suggested and showed for PHEV applications.

The initial results demonstrations that the capacity of a lithium-ion battery modules with thermal management system can be safely and fully operated even under extreme temperature and functioning conditions. Furthermore, the thermal management significantly increases the cycle life of a lithium-ion battery modules compared to equivalent modules without thermal management system. The recommended PHEV lithium-ion battery system is accomplished by meeting the car's power and stored energy capacity requirements and with a substantial decrease in occupied volume and charge time over lead acid battery [27].

A A Pesaran et al. introduced the thermal performance of electric car battery modules and packs. With the purpose of precisely design the thermal management system for electric cars, so thermal analysis should be conducted. Therefore, to get the estimate of the thermal performance, the heat transfer principles and finite element analysis software have been used [4].

Ahmad A Pesaran et al. also explained about the systematic approach in order to design and analyze the thermal management inside the battery pack. Thus the thermal management system is essential for maintaining and controlling the electric car battery pack temperature. They defined that the battery pack must be compatible with all modules so as to operate in the preferred temperature range. Besides, the uneven temperature distribution between the modules should be decreased towards minimizing the electrical imbalance and this result in improving battery performance and life cycle [26].

Tang et al. introduced an innovative method to manufacture lithium-ion polymer battery. In their research, simple process to coat the electrodes with micro porous composite polymer films have been conducted. Hence, the improved results that the graphite is protected by the composite polymer film from reacting with Mn^{2+} dissolved from the spinel $LiMn_2O_4$ cathode leads to the excellent performance of the NG anode [18].

Okamoto et al. worked on an implantable battery system and assessment of temperature rise of lithium ion battery. They figured out that lithium-ion battery and lithium-ion polymer battery have the same heat characteristics. Yet the internal resistance of the lithium ion battery is much larger. They defined that the lithium-ion polymer battery has the capability to keep cooler itself due to higher specific heat and lower internal resistance. Therefore, they concluded that lithium-ion polymer battery is more suitable for use in the implantable battery system because it has a benefit of temperature rise during operation [28].

Iwahori et al. developed the solid-state battery by using carbon material as the anode for the lithium-ion polymer battery technology in Lithium Battery Energy Storage Technology Reaserch Association (LIBES) research [15]. Cycle life and energy density of the battery technology have been improved in order to use it in electric car.

Sandy Thomas reported that the battery electric cars are used to labelled "green". This technology is to minimize the greenhouse gas and oil consumption from the transportation sector. Also, they found the higher specific power battery is required to improve and replace larger cars with a long driving capacity to make substantial reductions in greenhouse gas and oil consumption. Hence, they specified hydrogen and electricity can be made from lower carbon sources to further reduce the greenhouse gas in the future [29].

Ritchie and Howard found that the battery safety and battery cost are the main important factors in the usage of lithium-ion polymer battery in larger sizes [2], such as for electric cars. However, the lithium-ion polymer rechargeable battery has been developed for the telecommunication applications.

Pesaran et al. increased their attention to battery thermal management. They found that the performance and life of battery are affected by temperature. They described that thermal control is critical to ensure the battery performance and life. They also believed that with designing a good module and cell [30] can help them to improve the good thermal performance.

Bharathan et al. observed that the performance and life of battery in electric car can be affected by the operating temperature. They started designing good cells and modules to produce a good thermal performance using finite element analysis software. From the software, they captured both electrical and thermal behaviour of cells and modules [31]. They are planning to update their model from time to time including the chemical behaviour of the materials.

IV. CONCLUSION

The analysis is currently in preliminary phase involves gathering the recent literature reviews. The aim of this analysis is to study the efficiency performance of electric cars lithium-ion polymer battery by focusing and observing the influences of ambient temperature on the battery. Battery temperature affects battery performance, reliability and lifespan. High battery cell temperature may cause a shortening of the lifespan of the lithium-ion polymer battery caused by increased degradation of the battery cell.

Therefore, the battery thermal management is critical to achieve desired performance and calendar life for battery packs in electric cars.

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