Thermal Management of Batteries for Greater Energy Efficiency

André Cordeiro
André Souza
MAHLE Behr Gerenciamento Térmico Brasil Ltda.

ABSTRACT

The growing concern with the environment and the demand for reducing greenhouse gas emissions brings the need for innovative technological solutions, especially in the automotive world one of the solutions is electrification.

Figure 1. VW and Daimler publishing electrification for their vehicles.

Even with no regulations and/or incentives from Brazilian government, market predictions shows a sales increase of BEV Medium / Heavy vehicles, till 2035 4% of the production volume will be full eletric.

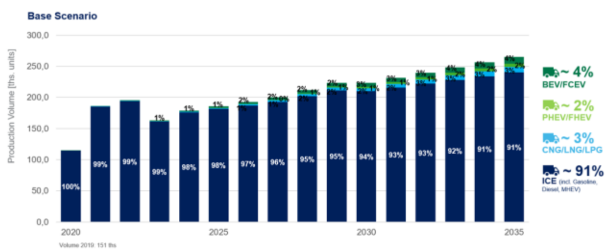

Figure 2. Expected heavy duty vehicles market share in South America – Baseline scenario.

The battery is one of the most important parts of the electric traction system. For automotive application, a working temperature within a specific range is required to ensure its full efficiency within a lifetime and safety. High and low temperatures can accelerate the aging of the battery system, reducing its service life, degrading its capacity and as a consequence its autonomy, bringing risks to the safety of the battery and its passengers.

The objective of this work is to deal with the system that guarantees the effectiveness and full functioning of the batteries, in use or during the critical period of charging. The BTMS (Battery Thermal Management System), is responsible for ensuring and facilitating the working conditions of the battery, granting thermal management, and consequently increasing efficiency, reducing weight and dimensions, ensuring a longer service life, vehicle battery capacity and safety. Thus, the implementation of electrification becomes possible allowing the protection of our environment.

INTRODUCTION

The electrochemistry of the battery is sensitive to high and low temperatures. Cell temperatures exceeding 45°C accelerate the aging processes to such an extent that the required lifetime of ten years or more is not assured. Temperatures below 10°C limit can even inhibit the usage of the battery at all. Furthermore, the battery electrochemistry tolerance of temperature gradients within the cell, and differences in temperature between the different cells in the battery module, is likewise only a few Kelvin. Altogether, it is fundamentally important to keep the battery in a non-critical thermal state under all operating conditions – this requires an efficient thermal management.

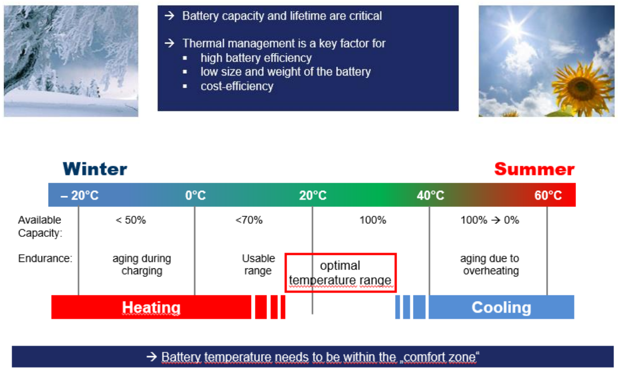

Figure 3. Temperatures conditions and its consequences.

In the battery, at the interface between electrochemistry and cooling, the battery's own significant thermal requirements clash with the requirements of the power train and the performance capabilities of the cooling or refrigerant circuit system. This interface is correspondingly complex. Therefore, a more extensive approach for thermal management for batteries is essential.

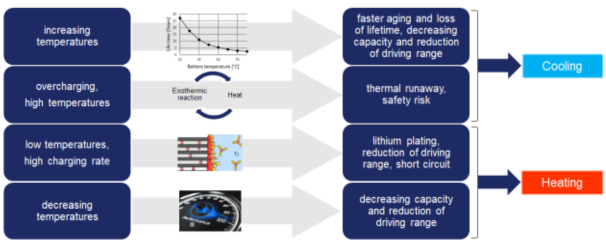

Figure 4. Possible behavior of the battery system when exposed to heat or cold.

Brazilian industry is mainly focusing on light/medium trucks applications, specially the ones that crosses capital cities with beverage or food and also developing full electric buses (small, medium or large), small vans are also playing along with some start-ups.

Figure 5. First Marcopolo's full electric vehicle.

Modern electric mobility will only find widespread acceptance when significantly shorter charging times for the electric energy storage can be achieved, which are currently still quite long. MAHLE already offers high-performance components that make fast charging possible.

In contrast to filling a tank with fuel, charging a battery is subject to losses. The faster the charging process, the higher the electrical current needed and thus the higher the losses due to heat. In order to rapidly charge the battery, while protecting it from premature aging, it must be subjected to active cooling that incorporates all existing cooling circuits, depending on the outside temperature. For rapid charging, for example, the air conditioning must provide up to 12 kW just for battery temperature control when the outside temperature is high. By way of comparison, current systems, dedicated solely to interior cooling, use about 8 kW [1].

Figure 6. Electric truck during charge

DEVELOPMENT

The goal of a thermal management system is to deliver a battery pack at an optimum average temperature (dictated by life and performance trade-off) with even temperature distribution (or only small variations between the modules and within the pack) as identified by the battery manufacturer.

However, the pack thermal management system has to meet the requirements of the vehicle as specified by the vehicle manufacturer it must be compact, lightweight, low cost, easily packaged, and compatible with location in the vehicle. In addition, it must be reliable, and easily accessible for maintenance. It must also use low parasitic power, allow the pack to operate under a wide range of climate conditions (very cold to very hot), and provide ventilation if the battery generates potentially hazardous gases.

A thermal management system may use air for heat/cooling/ventilation (Figure 1), liquid for cooling/heating (Figure 2), insulation, thermal storage such as phase change materials, or a combination of these methods. The thermal management system may be passive (i.e., only the ambient environment is used) or active (i.e., a built-in source provides heating and/or cooling at cold or hot temperatures). The thermal management control strategy is done through the battery electronic control unit [2].

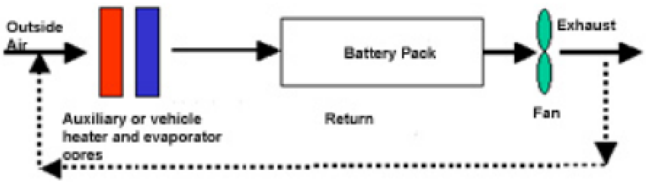

Figure 7. Schematic for air heating and cooling – outside or cabin air

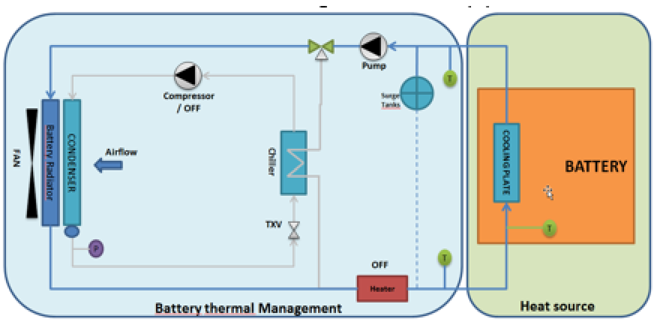

Figure 8. Schematic of Liquid Heating and Cooling

This paper will focus on liquid heating and cooling concepts considering three different driving conditions:

- Active cooling via chiller
- Passive cooling via radiator

- Heater via PTC

Product was developed integrating all components and systems to offer to the industry only one box with several varieties to attend all customer's requirements and desires, with minimum effort to install and communication with the vehicle's ECU.

Being loyal to the name BTMS (Battery Thermal Management System), our product can be mounted with the following components:

- Radiator
- Condenser
- Fan+Motor shroud
- Chiller
- Compressor
- TXV Valve
- Coolant Pump
- Expansion Tank
- PTC Heater
- 3-way valve
- Customer Interface

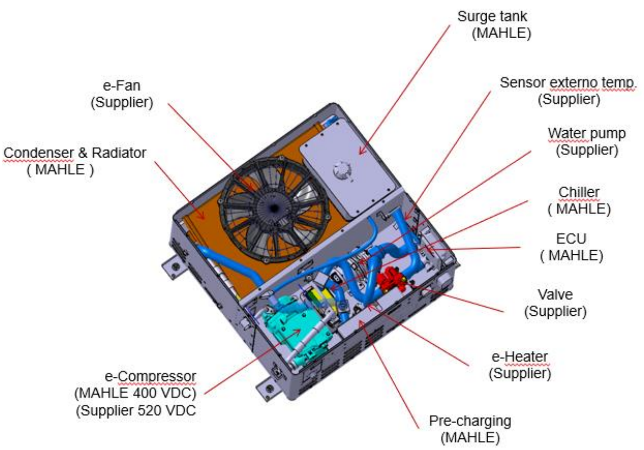

Figure 9. BTMS and its components.

Every component can be redesigned to fulfill performance and durability tests and our CAN communication can be switched to match customers plugs.

Basically, if the ambient temperature is below 18°C the passive cooling is working pumping coolant trough the radiator with air flow forced by the fan cooling the battery cell.

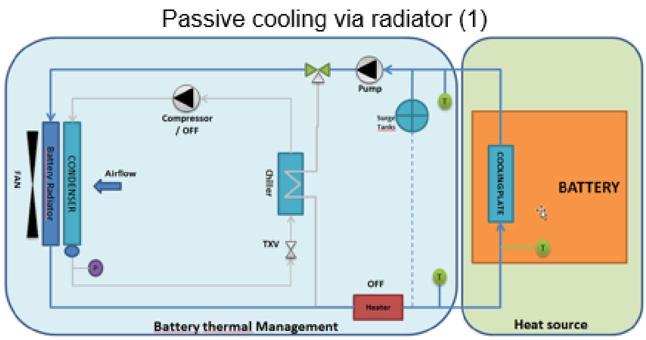

Figure 10. Passive cooling via radiator

With a range over the above specified the BTMS can easily and automatically switch to an Active cooling via Chiller, pumping coolant trough chiller, compressor is activated increasing the pressure letting the condenser does it works and decrease the temperature for the battery.

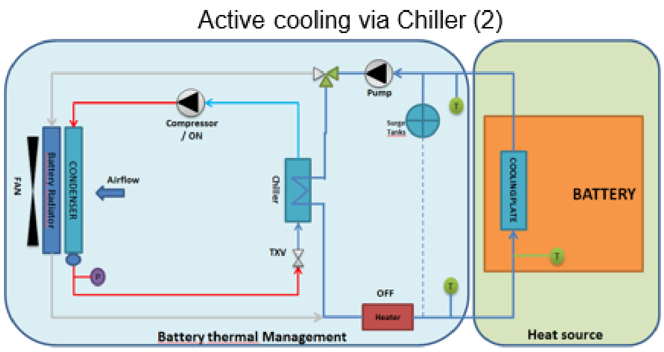

Figure 11. Active cooling via Chiller

As quoted before, cold ambient or cold batteries are not the best condition, such situation can decrease capacity, and reduce driving range and also lifetime.

For that, third mode will be able to heat the system and batteries to the temperature comfort zone and assure better performance and efficiency.

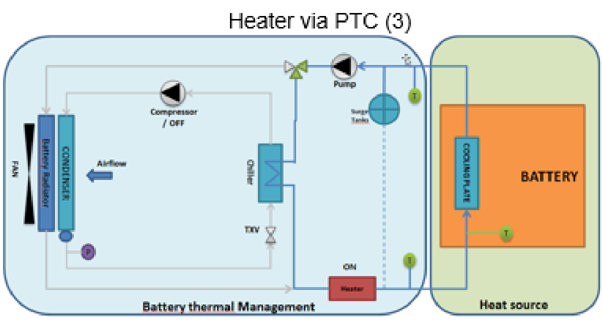

Figure 12. Heater via PTC.

CONCLUSIONS

A well-designed thermal management system is required to regulate battery pack temperatures evenly, keeping them within the desired operating range.

Production BEVs requires an active heating/cooling BTMS to allow them to operate in hot and cold climates. Proper thermal design of a module has a positive impact on overall pack thermal management and its behavior.

A thermal management system using air as the heat transfer medium is less complicated, though less effective, than a system using liquid cooling/heating. Generally, for parallel HEVs, an air thermal management system is adequate, whereas for BEVs, liquid-based systems may be required for optimum thermal performance.

Lithium batteries also need a good thermal management system because of safety and low temperature performance concerns.

The location of the battery pack may also have a strong impact on the type of battery thermal management and whether the pack should be air cooled or liquid cooled.

CONTACTS

André Cordeiro – Product Development Supervisor – email: andre.cordeiro2@mahle.com

André Souza – Product Engineer – email: andre.c.souza@mahle.com

NOMENCLATURES

BTMS – Battery Thermal Management System

°C – Celsius degrees

kW – Kilowatts

BEV – Battery Electric Vehicle

PTC – Positive Temperature Coefficient

ECU – Electronic Control Unit

TXV – Thermostatic Expansion Valve

EPP – Expanded Polypropylene

CAN – Controller Area Network

HEV – Hybris Electric Vehicle

REFFERENCES

1. Sophisticated Thermal Management for Li-Ion Batteries – from Evaluation of Thermal Cell Characteristics to Test Run of the Battery in a Climate Battery System Test Bench Achim Wiebelt, Dirk Neumeister, Matthias Stripf, Markus Kohlberger, Thomas Heckenberger Behr GmbH & Co. KG, Stuttgart