LI-ION AUTO BATTERY TEMPERATURE MONITORING DEVICE

VĂLIMĂREANU Beniamin[1], SAVCA Stelian[1], BUGHIANU George[1], VĂDUVA Rareș[1], GRIGORE Dănuț[1], OPRAN Constantin Gheorghe[2] and ILIE Cristian
[1]Faculty: Industrial Engineering and Robotics, Specialization: INPN/ IAAC/ IEMA, Year of study: 2,
e-mail: valimareanubeny@yahoo.com, steliansavca1997@gmail.com,
robertbughianu@gmail.com, grigore_danutz92@yahoo.com
[2]Faculty of Industrial Engineering and Robotics, Manufacturing Engineering Department

ABSTRACT: This work presents research on Intelligent Monitoring of Li-Ion batteries by analyzing their behavior under the influence of temperature in order to optimally maintain their functional parameters. The strategy for implementing an integrated temperature monitoring system is presented, in particular, if the permissible critical value is exceeded. The system consists of a structure that has the role of protecting and supporting the battery and an electronic monitoring equipment. Their purpose is to bring the temperature inside the operating system to a normal level, which does not affect the parameters of the battery. It is intended to prevent the risk of explosion or ignition, given that the structure of the battery contains chemicals that promote combustion and whose temperatures can reach up to 500 ° C. An important element of the intelligent system is the heating source which has the role of maintaining the battery temperature above a lower critical temperature under special operating conditions.

1. Introduction

The system for monitoring the temperature of the Li-ion battery consists of several elements such as: cooling source (fan), heating source, elements for mounting the system, the lower part of the housing and the housing cover, which is removably assembled from the lower part to allows you to change or check the battery later. The housing is made of a plastic with very good resistance to high temperatures (over 100 degrees Celsius) to withstand and operate in extreme environments. The dimensions are made according to the dimensions of the battery, so that the space between it and the inner surfaces of the housing is large enough to allow air to pass through (> 10-30 mm). The thickness is considered to be between 3 and 4 mm, which leads to a high strength of the system. There are also openings in the housing to allow the output of positive and negative terminals and a slot for mounting the fan, as well as an opening to remove air from inside. The devices for cooling and heating the battery are of the electric type and are connected directly to the battery, no need for an external source to power them. The fan used is chosen so that the volume of air supplied by it is more than sufficient for cooling and thus for the normal operation of the battery. It is also taken into account that its voltage value does not exceed 12V, and the number of rotations and the number of decibels (dB) it generates should not exceed a maximum value.

3. Materials for making products

The components of the device are made mostly of high temperature resistant plastics and have a good resistance against shocks and vibrations given the environment in which it operates, namely the engine compartment of a vehicle. The product design diagram is shown in figure 1.

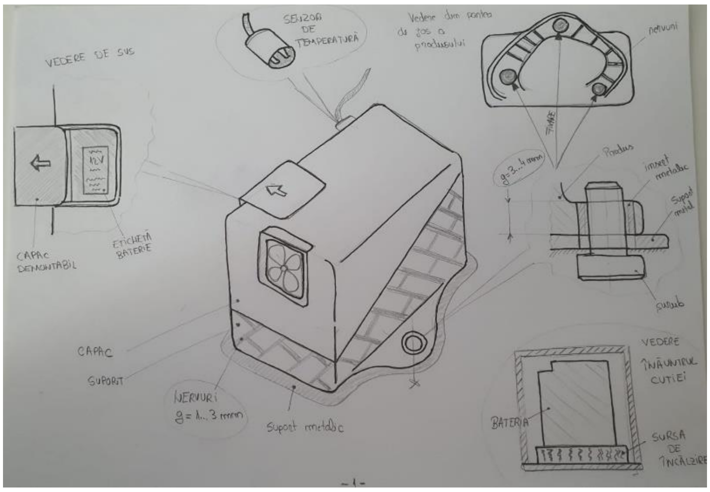

Fig.1. Product design scheme

The fixing of the casing will be done using a screw and a metal insert inserted in the plastic material, in the 3 areas it will be taken over all degrees of freedom. The thickness of the piece is about 3-4 mm to be resistant to shocks, vibrations, etc. and rib thickness 1-3 mm. The product is equipped with a simple temperature sensor that will signal when the battery temperature is critical. The removable cover (left side) is required so that the operator can see the details of the battery inscribed on its label.

The components of the device are:

1. bracket (bottom of the case)
2. cover (top of the case)
3. removable cover (side) - necessary for the operator to see the details of the battery marked on its label
4. metal inserts x3 (bottom) - required for assembling the product
5. x3 screws
6. main pipe (made of 2 components - the lower part and the upper part)
7. fan
8. temperature sensor
9. 12V battery

4. Assisted design

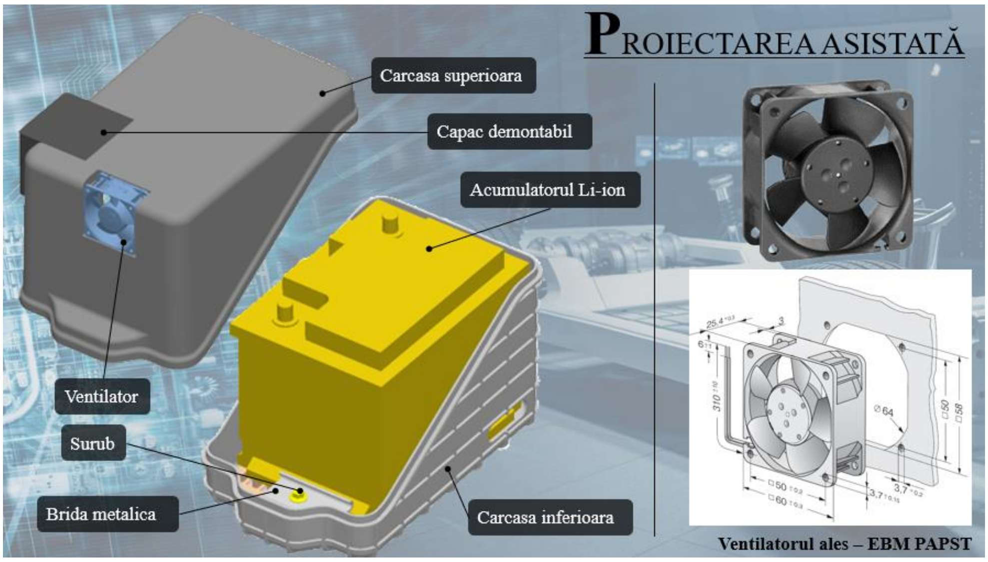

Fig. 2 - 3D design of the optimal product concept

5. Modeling - simulation

Modern engineering is so specialized and products so complex that it is difficult for a single person or team to design a product. Designers are increasingly using computers and software applications, with software being the catalyst that has revolutionized this process.

Initially, the computer was used to make drawings, a technology that later became computer-aided design (CAD) -based design. Subsequently, 3D representations of the parts that are part of the products were created. The next step was to take these models and run them on numerically controlled machines, and finally to process them on computer-aided machines. The methods used during product design involve software specific to mechanics, electronics, or design control methods and involve the ability to convert the model from one type of software to another. Standards have been developed to allow this, but sometimes the results have not been as expected, so the next step in the process is to unify the design, manufacture of components and management with the physical behavior of the product.

The process gives engineers the opportunity to be involved not only in the design and execution of the product, but also in the management of systems capable of simulating their performance, the result being the so-called virtual prototyping. Increasingly, simulation has taken the place of physical product testing, so more and more software packages specific to engineering design have included modules that allow the application of simulation tehniques.

Simulation of air flow and temperature

Initial data

The own contribution is the simulation of the air flow inside the housing, the definition of the parameters necessary for the simulation, as well as the realization of short presentations containing the simulation results and their interpretation. We have made sure that the battery temperature does not exceed 70 degrees Celsius in order to operate normally.

The simulation of the air flow inside the product (housing) was done in a software that contains a special module for its realization. For this study to be correct, it is necessary to define all the necessary parameters to be able to achieve air flow, such as: initial solid temperature, ambient temperature, type of fan used, pressure inside the housing, areas through which air is evacuated from inside as well as the area through which it enters the air duct. At the same time, we considered that the housing type product should be completely sealed, without air leaks.

His own contribution to this work is the simulation of the air flow inside the housing and the interpretation of the results.

The results of the simulation are presented below.

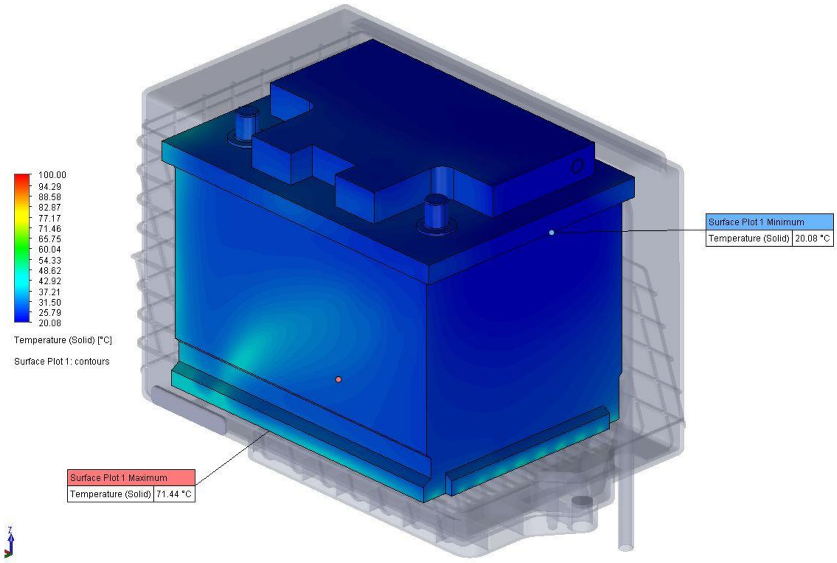

Fig. 3 - Battery temperature after simulation with fan on

A maximum temperature of approximately 71.5 ºC (on the bottom surface of the battery) is observed following the simulation with the fan on and a minimum battery temperature of 20 ºC, a temperature present on the surface in the immediate vicinity of the fan. The metal support on which the battery rests has a great influence on the temperature, being made of a metal, it has a much higher thermal conductivity.

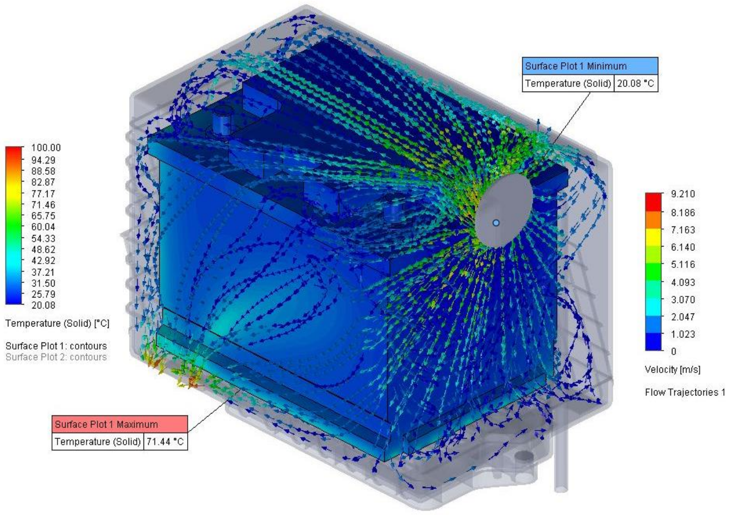

Fig. 4 - Simulation of the air flow inside the housing and the temperature of the battery with the fan on

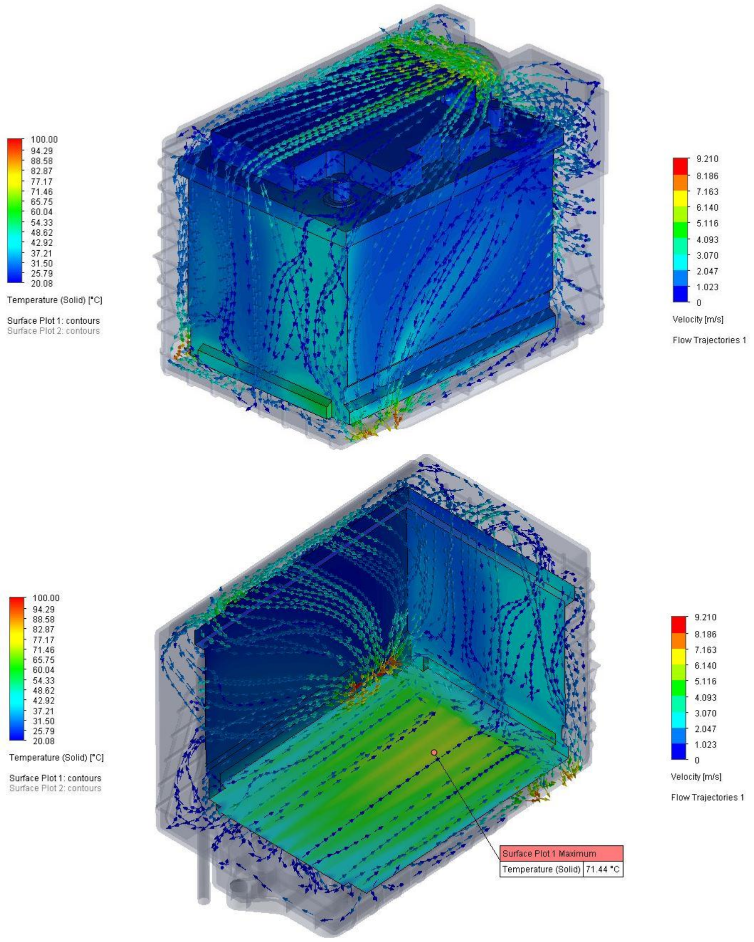

Fig. 5 - Flow directions and air velocity inside the housing (fan on)

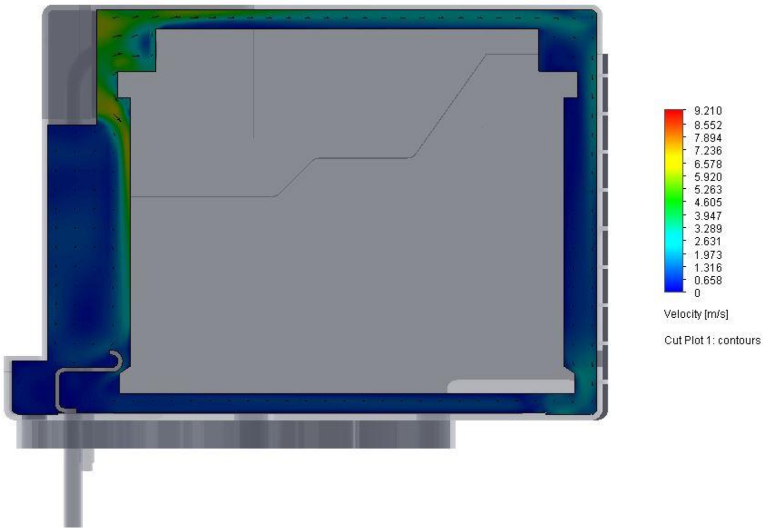

Figure 6 - Distribution of air velocity inside the housing (fan on)

The above figures show, as expected, a higher air speed in the fan area and a higher temperature of the fluid inside in the area where its speed is very low (bottom). The metal support is necessary to raise the battery to a certain height to allow the air to reach all surfaces, especially those in the lower area, where the temperature has the highest value.

The following study refers to checking the battery temperature when the fan is switched off and the airflow is generated only by the speed of the moving vehicle through an air duct, as shown in the figures below:

A very high value of the battery temperature is observed, of approximately 89ºC in its lower area, a value that influences its life and possible danger of explosion. This is the main reason why I chose to use a fan, as small and efficient as possible, which does not involve high costs and which reduces the battery temperature by a considerable amount.

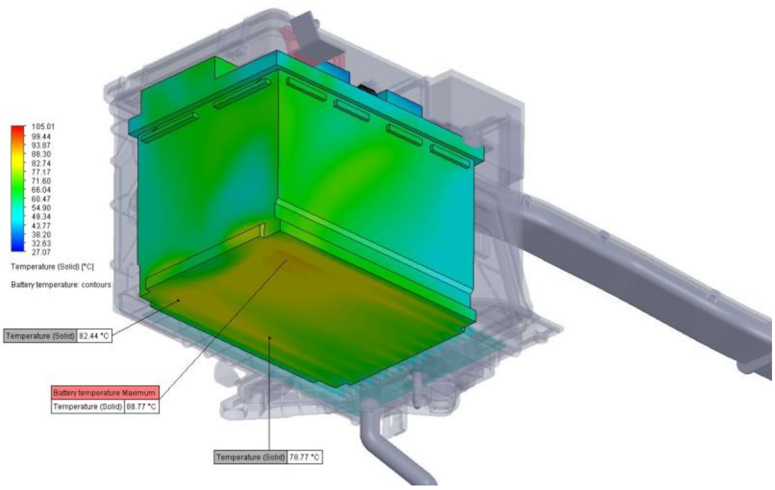

Fig. 7 - Battery temperature resulting from simulation with fan off

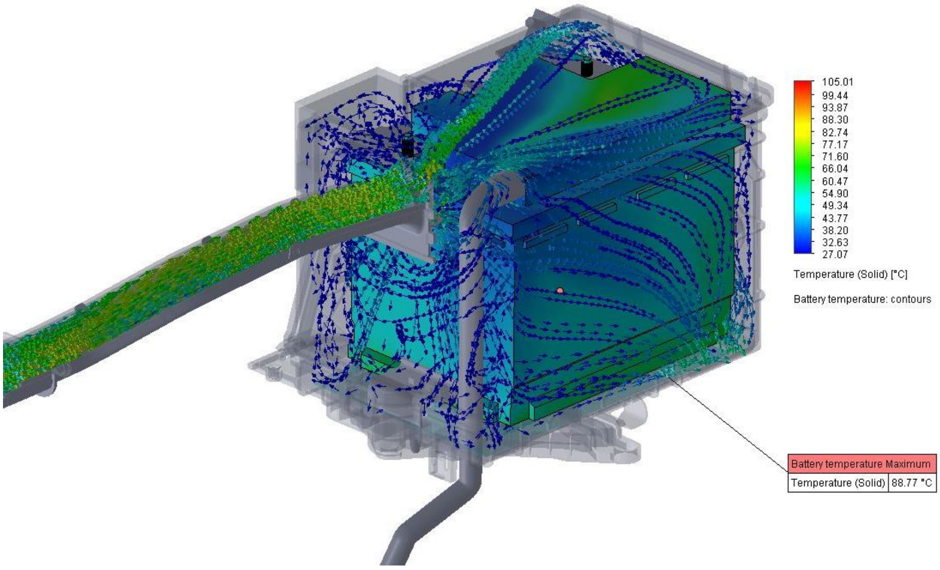

Fig. 8 - Air flow through the duct and then inside the housing (fan off)

From these simulations results the obligation to use a fan that considerably reduces the temperature of the Li-Ion battery, a temperature that resulted in approximately 71.5 ºC. The volume of air supplied by the fan is the same as that which enters it, which is why the volume of air entering the duct must be equal to them.

6. Future research directions

Based on this study, a multitude of applications can be made, such as replacing the fan with a larger one that provides a much larger volume of air, increasing the height of the metal support on which the battery is placed so as to penetrate as much air as necessary for cooling, use a temperature sensor (thermocouple) at the point where it turned out to be the highest temperature, etc.

7. Bibliography

[1] - ANKUR BHATTACHARJE, RAKESH MOHANTY, *Design of an Optimized Thermal Management System for Li-Ion Batteries under Different Discharging Conditions*, 30 October 2020

[2] – Chen, D.; Jiang, J.; Kim, G.; Yang, C.; Pesaran, *A. Comparison of different cooling methods for lithium ion battery cells*, J. Power Sources 2016, 94, 846–854

[3] – Daniel Cela Patrik Alerman - *Study of a 12V Li-ion Battery, Solution for Hybrid Vehicles* – Chalmers University of Technology

[4] – D. Di Battista, M. Mauriello, R. Cipollone, *Waste heat recovery of an ORC-based power unit in a turbocharged diesel engine propelling a light duty vehicle*, Applied Energy, 152 (2015) 109-120

[5] – E.S. Mohamed, *Development and analysis of a variable position thermostat for smart cooling system of a light duty diesel vehicles and engine emissions assessment during NEDC*, Applied Thermal Engineering, 99 (2016) 358- 372

[6] – Feng, X.; Sun, J.; Ouyang, M.; Wang, F.; He, X.; Lu, L.; Peng, H. *Characterization of penetration induced thermal runaway propagation process within a large format lithium ion battery module*, J. Power Sources 2015, 275, 261

[7] – Haimin Shi, Yiji Lu s.a., *Experimental study of multi- fans cooling module using different shroud structures for advanced vehicle thermal management system*, 9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

[8]–https*://www.hella.com/techworld/uk/Technical/Car-air-conditioning/Thermal-management-in-electric-and-hybrid-vehicles-1725/* accesat la data de 14.05.2021
[9] – Kim, J.; Oh, J.; Lee, H. *Review on battery thermal management system for electric vehicles,* Appl. Therm. Eng. 2019, 149, 192–212
[10] – Krüger, I.L.; Limperich, D. *Energy Consumption of Battery Cooling in Hybrid ElectricVehicles. In Proceedings of the International Refrigeration and Air Conditioning Conference*, West Lafayette, IN, USA, 16–19 July 2012
[11] – M. Park, D. Jung, M. Kim, K. Min, *Study on the improvement in continuously variable transmission efficiency with a thermal management system,* Applied Thermal Engineering, 61 (2013) 11-19
[12] – SCHIAVON, Stefano, MELIKOV, Arsen, *Introduction of a Cooling-Fan Efficiency Index,* UC Berkeley HVAC System, November 2009, Volume 15, number 6
[13] – Shuai Ma, Modi Jiang, s.a, *Temperature effect and thermal impact in lithium-ion batteries: A review,* Progress in Natural Science: Materials International, 28 (2018) 653-666
[14] – T. Wang, A. Jagarwal, J.R. Wagner, G. Fadel, *Optimization of an Automotive Radiator Fan Array Operation to Reduce Power Consumption*, IEEE-ASME Trans. Mechatron., 20 (2015) 2359-2369
[15] – Tanabe et al. 1994; Tsuzuki et al. 1999; Melikov et al. 2002; Watanabe et al. 2005; Sun et al. 2007
[16] – Yuksel, T.; Litster, S.; Viswanathan, V.; Michalek, J.J. *Plug-in hybrid electric vehicle LiFePO4 battery life implications of thermal management, driving conditions, and regional climate*, J. Power Sources 2017, 338, 49–64