Thermal Analysis of a Li-Ion Battery using FloEFD Software

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ABSTRACT. In the presented study, a thermal analysis of a lithium-ion battery was carried. The battery consists of 6 Series 2 parallel, 12 lithium-ion (NCA 18650) batteries. Liquid water was used as a refrigerant in the thermal analysis of the battery. After designing in SOLIDWORKS computer-aided design program, performance of the battery module was investigated with the help of SIEMENS FloEFD program which is a computational fluid dynamics program. The simulations were performed under steady-state conditions by using the k-epsilon turbulence model. The results bring out that the highest temperatures were occurred at the busbars and the liquid cooled batteries can operate efficiently at a temperature of 27-28°C.

1. INTRODUCTION

Due to the ever-increasing customer demands that push the limits of our imagination, a rapid technological consumption is experienced in every field from transportation to communication, from health to defense. At the presented time, it is known that almost every individual has at least one of the portable electronic devices (computers, mobile phones, cameras, cameras, MP3 players, CD players, DVD players, radios, televisions) for fast, efficient and easy communication [1]. In addition, most of the electrical appliances we use at home are becoming wireless. The basic condition for long-term and effective use of all these wireless portable electronic products is to have an energy source with high energy density, safe, long-lasting, easy to maintain, rechargeable in a short time and does not harm the environment. Lithium-ion batteries are widely used today in portable electronics and electrical equipment due to their superior features [2]. For this reason, studies, research and developments on lithium-ion batteries have increased over the years.

The biggest factor affecting the performance of batteries, one of the main parts of electronic devices and electric vehicles, is temperature. Too high or too low temperature can directly affect battery performance and reliability, leading to a capacity reduction. And in extreme cases, it can cause permanent deterioration even with thermal runaway [3,4]. Therefore, efficient and stable thermal management is key to battery systems. At the presented time, CFD technology has developed rapidly with the improvement of numerical computing method and computer performance [5]. Computational fluid dynamics programs can be used to investigate and make improvements to the heat flux fields and thermal management of coils. According to the heat transfer medium, the cooling method of the battery thermal management can be divided into three different types, respectively air cooling, liquid cooling and phase change cooling [6]. Xu and Sun [7], used CFD methods to study the air-cooled battery pack based on field synergy principle. The results showed that raising air speed and decreasing air temperature can increase the field synergy number, thereby improving the heat dissipation performance of a battery. Saw et al. [8], utilized CFD method to analyze the air cooled battery pack containing 38, 120 cells. The simulation results indicated that increasing the cooling air flow rate will cause higher heat transfer coefficient and pressure drop [9]. To build a whole battery pack and its cooling system is much more

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difficult than to build a single battery module with a liquid cooling plate [10].

Peng et al. [11], examined the optimal configuration of an air cooling (AC) system for a cylindrical battery pack. As a result, different configurations have been introduced so that the battery can operate at a more favorable temperature.

In this study, the thermal performance of a battery cooled with liquid (water) cooling was analyzed numerically with the help of SIEMENS FloEFD program.

2. MATERIALS AND METHODS

In this study, it was aimed to investigate the thermal performance of a battery cooled with liquid (water) cooling. In line with this aim, the thermal model of lithium-ion batteries was examined, and the temperature values of the battery were calculated. A lithium-ion battery pack and cooling system firstly was designed with SOLIDWORKS computer-aided design program. The liquid cooled battery module is generally composed of batteries, bus bars, liquid cooling system and other parts. The operation of the liquid cooling system is directly related to the performance and efficiency of the battery module.

In Figure 1, the sequence of the design of 12 batteries (6 series 2 parallel) is shown in section a. In Figure 1, the arrangement of the busbars is shown in part b. In Figure 1, in part c, an outer aluminum case is designed.
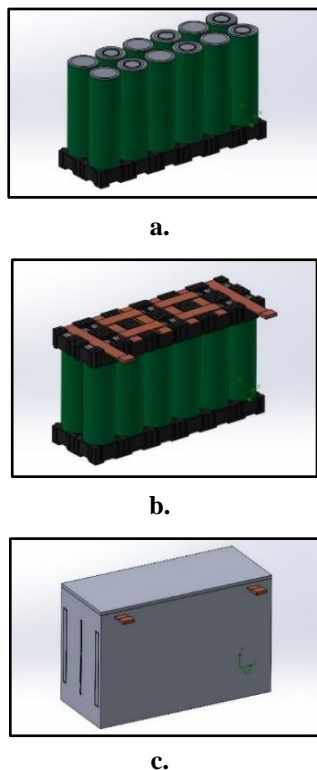

a.

b.

c.

Figure 1. The design stages of the battery **a.** Arrangement of batteries **b.** Arrangement of busbars and batteries **c.** Outer casing

The lithium-ion battery, which was designed in the SOLIDWORKS program, was created in the SİEMENS FloEFD program. In the thermal model preparation part, the computational domain in which the analysis will take place has been created. After the computational domain has been established, the boundary conditions of the lithium-ion battery are determined.

In Figure 2, computational domain was created in part a to perform battery analysis. In Figure 2, boundary conditions are entered in part b. The inlet velocity of the liquid (water) used as a coolant is given as 0.5 m/s. Its output is defined as ambient pressure. 12 Amps current is defined in the input part of the battery. The output voltage is also defined as zero.

Equivalent circuit model is used while performing battery analysis in Siemens FloEFD software. In the equivalent circuit model, the battery is subjected to a power-current test. The change of state of charge (SoC) in these tests and the temperature distribution on the battery are shown. In the equivalent circuit model in the Siemens FloEFD program, the current must be active in order to complete the circuit working behind the program and to see the temperature distribution in the batteries. In order to complete the circuit on the program and to activate the current, the voltage value is given as zero (0).
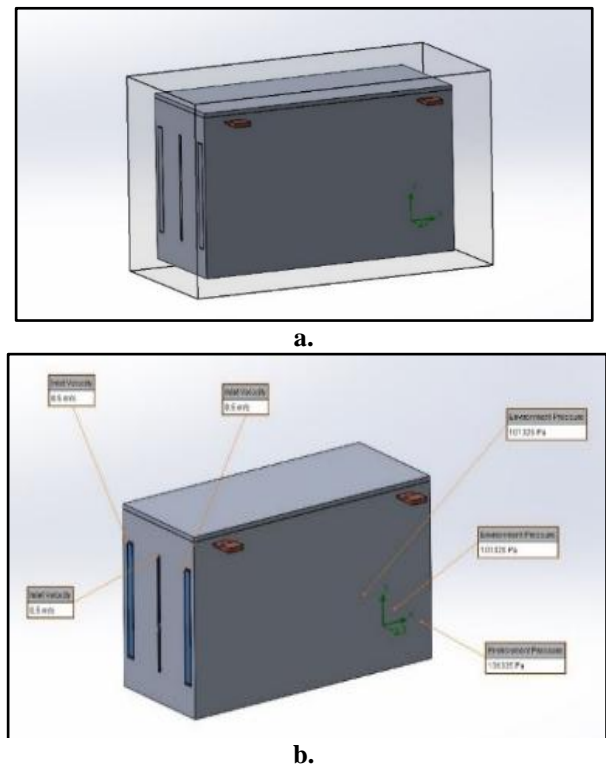

a.

b.

Figure 2. a. Computational domain
b. Boundary conditions

After determining the computational domain and boundary conditions of the lithium-ion battery, the meshing part was started. In the lithium-ion battery, the global mesh and local mesh was discarded. Figure 3 shows the mesh structure created in the coil. As can be seen in the figure, mesh density has been established on important places where the analysis will take place

(cooling system, etc.) There are a total of 955,000 elements in the mesh structure created. After completing the computational domain, boundary conditions and mesh structure, the thermal analysis of the battery was carried out.
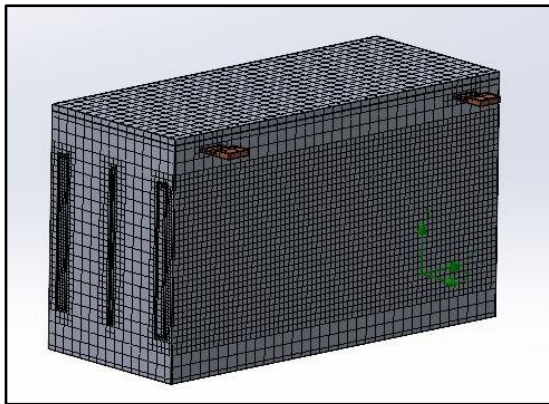

Figure 3. Mesh Structure

3. CONCLUSIONS

Thermal analysis of the lithium-ion battery was carried out. Thermal analysis results were given in Figures 4 and 5. The results clearly show the heat zones of the battery cells and the distribution of this heat in the battery.

Temperature distribution in the outer aluminium case of battery was plotted in Figure 4. As is apparent from this figure, temperature intensity is higher especially at the ends of busbars.

Figure 5 shows the temperature distribution inside the battery in order to see clearly thermal analysis results of the internal parts of the battery (batteries, busbars, battery bed, etc.). The liquid-cooled system used in the battery pack has enabled the batteries to work efficiently at 27-28°C. Temperature is higher in the busbars, inlet and outlet areas of the battery.
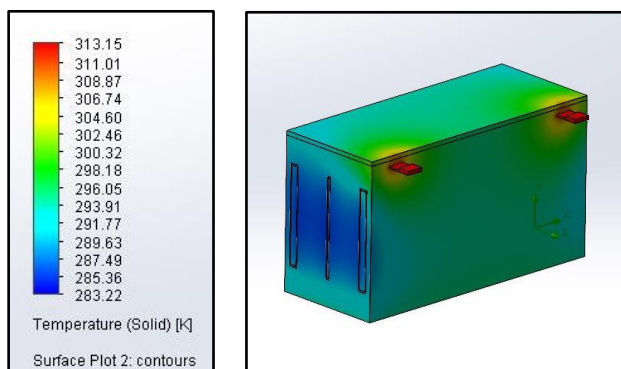

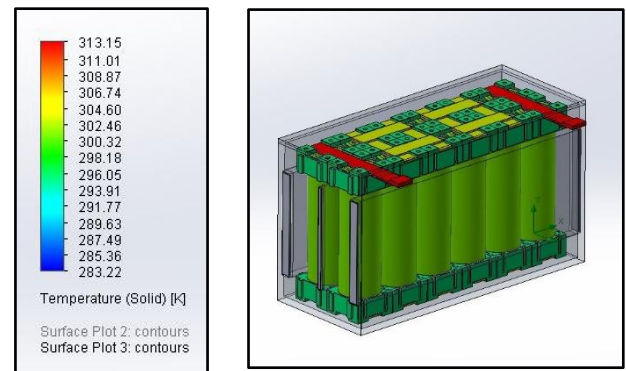**Figure 4.** Temperature distribution in the outer aluminum case

Figure 5. Temperature distribution inside the battery

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