HISTORY OF ELECTROMOBILITY, FUTURE BATTERY TRENDS AND HOW TO MEASURE THEM

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Abstract: This work deals with the description of the development of electromobility from history to the present day. Problems associated with the use of silicon in anodes and a measuring system for testing the volume changes of batteries are also mentioned.

1 INTRODUCTION

Today's world is full of electrification, it is due to the fact that we can relatively easily get and transform electricity from renewable sources. This causes (r)evolution in all directions of our lives. One of the big industries affected by this big change is automotive. The whole industry is trying to adapt and introducing certain degrees of electrification to most models on the market.

2 ELECTROMOBILITY

While electromobility may seem to be a trend of modern years, it certainly is not. Inventors created their prototypes as early as the 19th century. In 1884, the British inventor Thomas Parker began producing the first production electric car in Britain, thus two years ahead of Karl Benz. Electric cars at that time used lead-acid batteries for propulsion, so they had a short range and were heavy, another disadvantage was that in most cases the batteries had to be removed from the vehicle to recharge them. The big advantage, however, was that they achieved much higher performance and speed. Because of the development of internal combustion engines and the complex handling of heavy batteries, the electric drive was abandoned. Occasionally a manufacturer came up with a model powered by electricity as a demonstration of this technology. One of these vehicles is the BMW 1602e, which served in the parade of the Munich Olympics games. You can see the vehicle on the figure 1 [1].

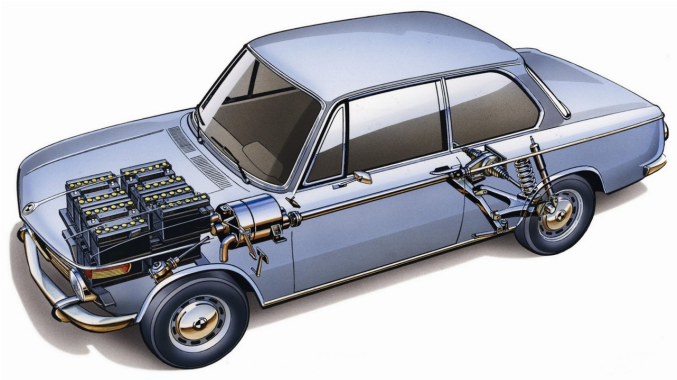

Figure 1: BMW 1602e [2]

The interest in alternative propulsion was started during the oil crisis in the 1970s. At that time, new battery technologies such as Ni-Cd and Ni-MH batteries were already appearing on the market. First, Ni-Cd batteries were used, vehicles with these batteries had a range of about 100 km, later these batteries were replaced by Ni-MH batteries It was because cadmium is toxic and Ni-MH batteries were also able to offer a higher gravimetric energy density. In this days we can find Ni-MH batteries in some hybrid vehicles [1].

Ni-MH battery The anode of the battery is made of an alloy of metals, it is reaction with hydrogen and produce hydrides (MH). The cathode is made of nickel hydrooxide (NiO(OH)). Potassium hydroxide solution (KOH) serves as the electrolyte. Today, they are used mainly as a replacement for disposable cells. Their advantages are a good price/capacity ration, it has no memory effect and does not contain toxic substances, as a minus we can mention self-discharge, but this has been significantly reduced in today's modern batteries [3].

A new era of electric vehicles began in the 1990s when the world start focusing on ecology and also on the fact that fossil fuel reserves are not infinite. That fact forced car manufacturers to produce their own electrified vehicles, but this cars did not attracted lots of customers. It was due to several aspects. That vehicles had a short range, were expensive, had very limited performance, and another limitation was the almost non-existent infrastructure. One of the 1990s representatives is the GM EV1, which is shown on figure 2 [1].

Figure 2: GM EV1 [4]

The modern boom in electric vehicles was unleashed by Tesla with its model Roadster (figure 3), which began production in 2008. It was the first production electric car which overcome 300 km range. Every car manufacturer on the market produces an electric vehicle. It it because of demonstration of technological sophistication and efforts to reduce fleet emissions. All modern electric cars use Li-ion batteries [1].

Figure 3: Tesla Roadster [5]

Li-ion battery It is the latest and most dynamically developed technology in the field of batteries. The technology of lithium-ion batteries allows use of several types of anode and cathode materials. The most commonly used anode material is carbon (C), lithium titanium oxide (LTO) or silicon (Si). In the case of cathode materials, the aim is to reduce the use of cobalt as much as possible and preserve properties. Today, the most common technologies are lithium nickel-manganese-cobalt oxide (NMC), lithium iron-phosphate (LFP) and lithium nickel-cobalt-aluminum oxide (NCA), there are also lithium-cobalt oxide (LCO) and lithium-manganese oxide (LMO). The electrolyte is a lithium salt dissolved in an organic solvent. This is the most widely used type of battery today, and can be found in all types of wearable electronics, electrified vehicles and in energy storage. The biggest advantages of these batteries are large volumetric and gravimetric capacity, low self-discharge, large terminal voltage, etc., the disadvantages include the high cost, the need of battery management and more complex recyclability [3].

2.1 Implementation of batteries in an electric car

The battery of an electric car is a complex element whose price exceeds the rest of the components in electric vehicles. The battery pack contains cooling, a control unit, battery management system (BMS) and a several battery modules. The battery pack is designed to make the best use of the vehicle's space and to be able to occupy the vehicle with as many batteries as possible, usually the batteries are stored in the floor of the crew cabin, which strengthens the entire structure. One of the parameters that determines the maturity of the carmaker is the gravimetric capacity of the whole pack. The battery has a voltage between 300-400 V.
Battery modules contain individual battery cells, they can contain cooling and heating, or secondary control units and temperature sensors. Figure 4 shows an divided battery.
The BMS is a control circuit that serves to monitor the voltage of individual cells, and also controls the charging and discharging of individual cells so that they do not exceed the permitted voltage limits. It also monitor the temperatures of the batteries and allow to limit the power flow from the batteries. At the same time, it is balancing the voltage of individual cells, because as the batteries age, it begins to happen that the voltage on all batteries is not the same.

Three types of cells can be used in the modules. Each type of cell has some advantages and disadvantages. The first type are roller batteries. These batteries resemble ordinary disposable cells and come in several sizes. Their advantage is easy thermal management, the biggest disadvantage is the low volumetric density of battery modules, because the batteries can not effectively use the entire space.
The second type are prismatic cells. These cells have the shape of a block. Thanks to their shape,

they allow full use of the space in the pack and, thanks to the solid packaging, they have a relatively easy temperature management, the disadvantage is the smaller volumetric capacity of the batteries.
The third type of battery is a cell cell. The batteries can be of any shape, usually rectangular. They use non-conductive foil as packageand. This is the most widely used type of battery today. Their advantage is a large volumetric capacity and the disadvantage is more demanding temperature management [3].

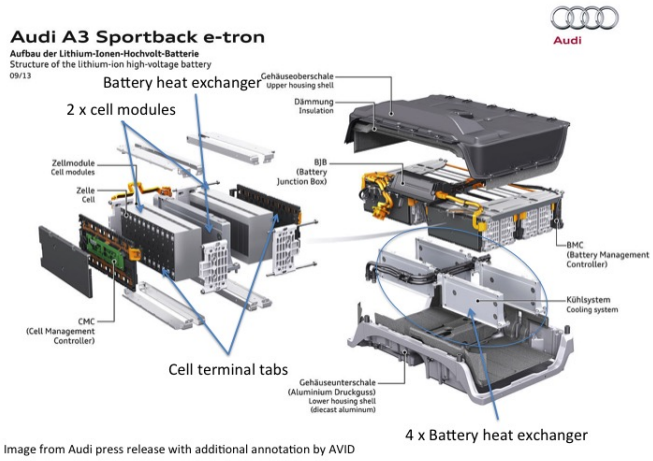

Figure 4: Look inside the Audi A3 battery [3]

2.2 Behavior of new Li-ion batteries

Following the efforts of the new Li-ion batteries, it is necessary to focus on both cathode and anode technology. Carbon is most common anode material today, it has a theoretical gravimetric density of 375 mAh/g. In this days, in some cases, is anode doped by silicon in range of 5-10 %, but in the future it is expexted that the doping will increase up to 40 %. The size of the doping will also affect the growth of the anode capacity. Silicon has a theoretical gravimetric capacity of 4000 mAh/g.

The biggest problem in using a combination of silicon and carbon is that silicon can increase its volume by up to 280 % during cycling. Combined with use in pouch cells, this will lead to battery expansion. It is necessary to verify how will expansion affected other batteries in electric vehicles. It is because of closely stacking in module.[6].

3 MEASUREMENT OF VOLUME CHANGES OF CELLS

I designed the construction of the device in the SolidWorks program which will serve to study the cells at a certain pressure or measure the pressure generated by the battery during expansion. Device could be used for both of these cases.
The device will consist of four metal clamps, which will be used for making pressure, two wooden boards will be used for insulation and pressure distribution from the metal clamps, the top wooden board will be fastened with screws to clamps to reduce the effect of its own weight on the battery. The top plate will be in two versions, the first will serve to create a constant pressure on the battery, in the second case will be piezoelectric sensors attached to the plate to measure the volume changes of the battery cell.

The clamp consists of two metal straps, which are connected at the edge with screws and a nut to tighten the joint. A spring will be mounted on the screw to eliminate the effect of the clamp weight. The whole assembled device is shown on the figure 5.

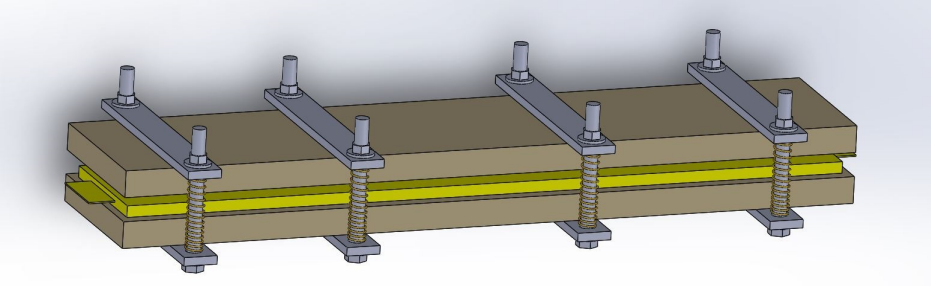

Figure 5: Device for measuring battery volume changes

4 CONCLUSION

As I described in this post, electromobility is a future transport trend. There are still many things that can affect the operation of electric vehicles. This test which was described in this article will serve to Škoda Auto to improve their electric cars. Batteries which will be used for this test are from real electric vehicles. The output should be a verification of how much the pressure load affected the battery performance.

ACKNOWLEDGMENT

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