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TESTING OF BATTERIES USED IN ELECTRIC CARS EVALUATION OF THE SMALLEST POSSIBLE CURRENT REQUIRED TO TEST THE FAULTS OF THE TRACTION BATTERY GRID

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Abstract:

The presented article presents the parameters of batteries used in electric cars. Measurements were performed for different types of batteries. The process of charging and subsequent discharging of these batteries took place. Different types of loads were used to discharge the batteries to find the smallest possible load current, which identifies the faults of the battery grid.

1 Introduction

Lithium-ion batteries have been used successfully in everyday life, from 3C products to EV (Electric vehicle), etc. If we introduce a newly developed lithium-iron phosphate (LiFePO4) battery with greater energy capacity and safer chemical properties, it was considered an excellent source of energy. Identifying damaged battery cells is therefore a topic that needs to be addressed in order to eliminate the additional costs associated with using the battery.

The main reason for the widespread expansion of lithium cells is the low rate of self-discharge, high capacity and relatively high specific energy. Due to the growing demand of industry for reliable, high-energy and small-scale energy sources. The decisive feature in lithium cells is in particular the energy density, which depends on the material of the electrodes. In *Fig. 1* is a comparison of energy density and specific energy of current cells with older types of batteries. In comparison, there is a lead-acid battery, nickel-cadmium, nickel-metal hydride, lithium polymer and lithium ion. From the graphical interpretation we can see that the li-ion battery has the highest specific energy and energy density. [1]

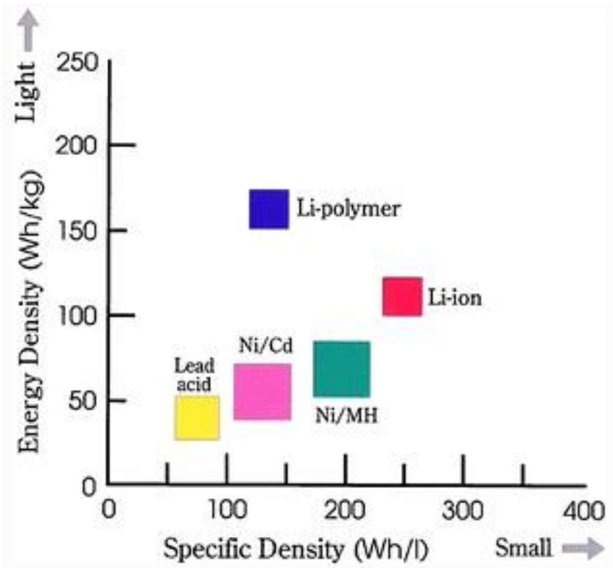

Fig. 1 Energy density versus specific density diagram for various types of batteries [1]

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Initially, lithium batteries were produced as primary batteries, a type of battery that cannot be recharged. During electrochemical, the substances needed to generate electricity were consumed. Oxidation-reduction processes are irreversible and gassing and possible electrolyte leakage occurs when recharging. The advantages of primary cells are high energy density, low weight and relatively low cost due to single use.

The first secondary types of lithium cells encountered problems such as overheating and explosions. From a safety point of view, it was necessary to replace lithium metal with a less aggressive material. In 1991, Sony introduced a rechargeable lithium cell consisting of a graphite anode and a cathode of cobalt oxide. [2]

Lithium-ion batteries vary in terms of the internal structure material used. They acquire specific properties based on the use of a combination of selected materials for the anode, cathode and separator. The electrolyte is formed through a lithium salt. The intercalation process is the basic principle for the operation of a lithium-ion cell. Intercalation electrodes are composed of compounds that allow lithium ions to be embedded in the crystal lattice of another substance. The host structure into which the ion has been placed through intercalation will change. The result is an intercalating compound called an intercalate. The intercalation process is chemically or thermally reversible.

During operation, lithium-ion batteries are exposed to an aging process that results in a loss of cell capacity and performance. *Table 1* shows the effects of processes on article parameters.

Table 1 Influences of processes on article parameters

Process	Effect	Influence	Cause
Electrolyte decomposition	Loss of lithium Increase in internal impedance	Decrease in capacity Decrease in power	High temperatures High State of Charge (SOC)
Solvent intercalation, gassing and subsequent cracking in particles	Loss of active material and lithium	Decrease in capacity	Overcharging
Reduction of the surface area due to the continued formation of the Solid Electrolyte Interface (SEI) layer	Increase in internal impedance	Decrease in power	High temperatures High SOC
Changes in porosity due to volume changes, SEI layer formation	Increase in internal impedance Surplus potentials	Decrease in power	High cycling rate High SOC
Loss of active material particles due to volume changes during cycling	Loss of active material	Decrease in capacity	High cycling rate High Depth of Discharge (DOD)
Binder decomposition	Loss of lithium Loss of mechanical stability	Decrease in capacity	High temperatures High SOC

The cathode material is one of the most expensive parts of the lithium-ion battery and significantly affects the final price. The cathode materials are prepared in a discharged lithium state (when they contain lithium atoms) so that they can be paired with anodes that do not contain lithium atoms. When maximizing energy density, it is important that the potential between the cathode and anode material is as high as possible. This requirement limits the choice of cathode materials to transition metal compounds such as manganese, iron, cobalt and nickel. Oxides and polyanionic compounds of transition metals are also used for cathode materials.

Cathode materials must meet the following requirements [19]:
• Ability to intercalate large amounts of lithium

• Ability to deintercalate lithium without structural changes
• High energy value
• High potential due to lithium
• Compatibility with other materials in the article
• Insolubility in the electrolyte
• Low preparation costs
• Good electron conductivity

Over time, many electrode materials have been developed and subsequently studied, which are still commercially available today. Most of the investigated commercially available cathode materials contain a layered structure ($LiNiO_2$, $LiCoO_2$). Unlike previous materials, $LiMn_2O_4$ has a spinel structure. This material is important in the commercial sphere because it does not fall under the Mizuchimov and Goodenough patent of 1981. The patent only applies to oxide compounds that have a layered structure. [3]

In terms of time, we can divide the cathode materials into:
• First generation ($LiNiO_2$, $LiCoO_2$)
• Second generation ($LiFePO_4$, $LiMn_2O_4$, $LiNi_{1-x}Co_xO_2$, $LiMnO_2$, $LiMn_{1-x}Co_xO_2$, $LiNi_{1-x}Mn_xO_2$, $LiNi_{1-x-y}Mn_xCo_yO$)
• Third generation ($LiCoPO_4$, $LiNi_{0.5}Mn_{1.5}O_4$)

Table 2 Cathode materials and their basic parameter differences [3]

Material	Structure	Average voltage potential versus lithium [V]	Theoretical specific capacity [mAh/g]
$LiCoO_2$	Layered	3.88	130-160
$LiNiO_2$	Layered	3.55	200
$LiMn_2O_4$	Spinel	4.10	100-130
$LiFePO_4$	Olivine	3.45	140-170

2 Experimental details

Zhidou D1 electric car batteries were used for the measurement. The complete battery pack of the vehicle is composed of cells, type LiFePo4. The capacity of each cell is 150Ah. The battery pack has been used for about 6 years on the vehicle. We used three types of loads for the measurement. The first load is 15A, which is 0.1C. The second load is 60A, which is 0.4C. The third load is 120A, which is 0.8C. The measurement was made from a minimum current of 15A to a current of 120A. The voltage ranges used on the batteries were based on the values of how the batteries are used by the vehicle. We set the minimum value of the battery voltage during the measurement to 2.8V, because the vehicle switches off the entire battery pack if the voltage on any cell drops below 2.8V (with or without load). We set the highest voltage on the cell to 3.60V. For the measurement, we used a load from Chroma ATE Inc., model 63203E-150-300.

3 Results and discussion

3.1 Measured results of load 15A – 0.1C

Load 15A – 0.1C, battery 3144-14

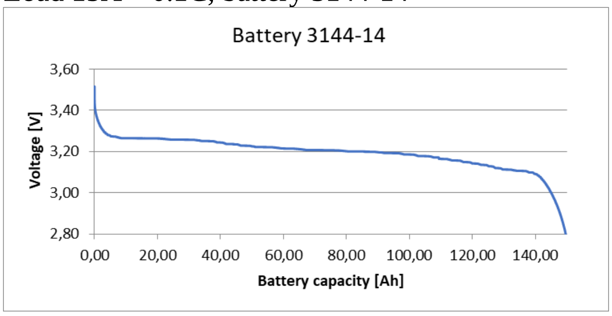

Fig. 2 The course of voltage on the battery 3144-14 at a load of 0.1C, final battery capacity 145.57Ah

Load 15A – 0.1C, battery 3144-15

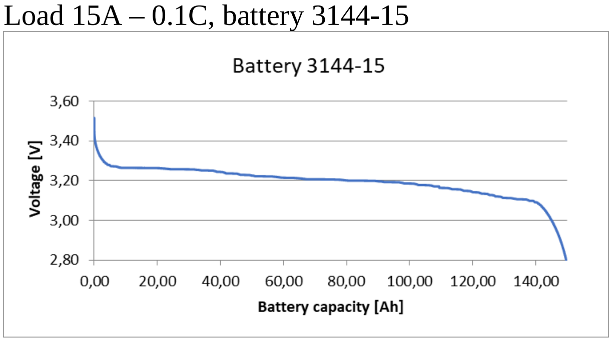

Fig. 3 The course of voltage on the battery 3144-14 at a load of 0.1C, final battery capacity 146.01Ah

Load 15A – 0.1C, battery 3618-14

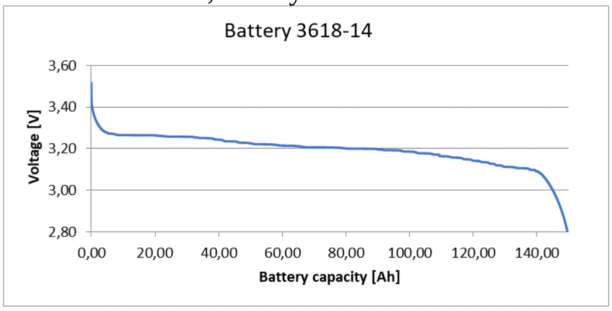

Fig. 4 The course of voltage on the battery 3618-14 at a load of 0.1C, final battery capacity 148.65Ah

Load 15A – 0.1C, battery 3618-16

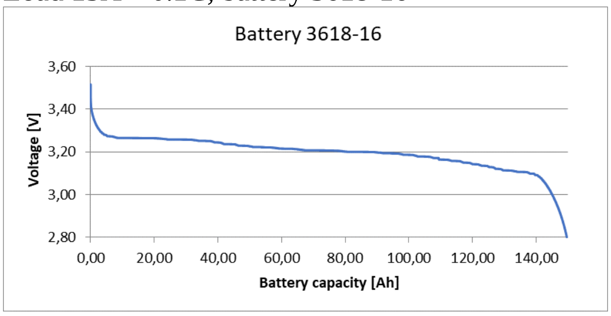

Fig. 5 The course of voltage on the battery 3618-16 at a load of 0.1C, final battery capacity 149.62Ah

3.2 Measured results of load 60A – 0.4C

Battery 3144-14

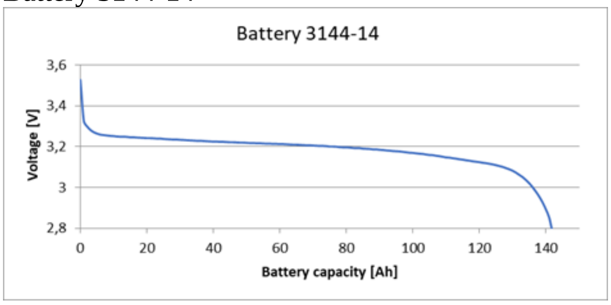

Fig. 6 The course of voltage on battery 3144-14 at load 0.4C, final battery capacity 141.76Ah

Battery 3144-15

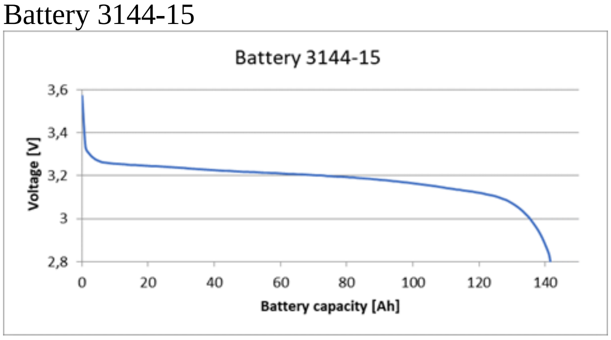

Fig. 7 The course of voltage on battery 3144-15 at load 0.4C, final battery capacity 141.46Ah

Battery 3618-14

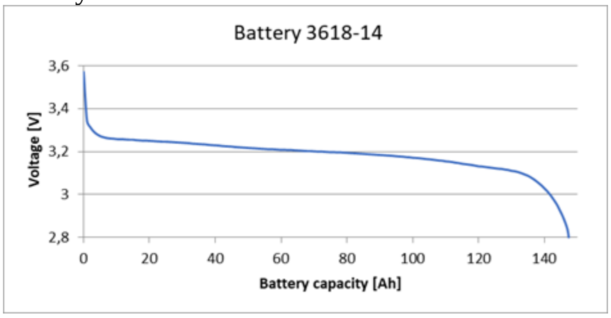

Fig. 8 The course of voltage on the battery 3618-14 at a load of 0.4C, final battery capaci-ty147.38Ah

Battery 3618-16

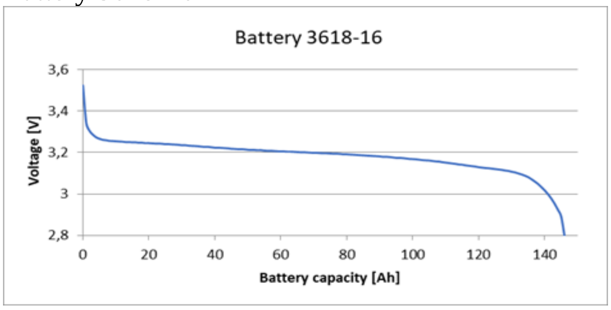

Fig. 9 The course of voltage on the battery 3618-16 at a load of 0.4C, final battery capacity 146.00 Ah

3.3 Measured results of load 120A – 0.8C

Battery 3144-14

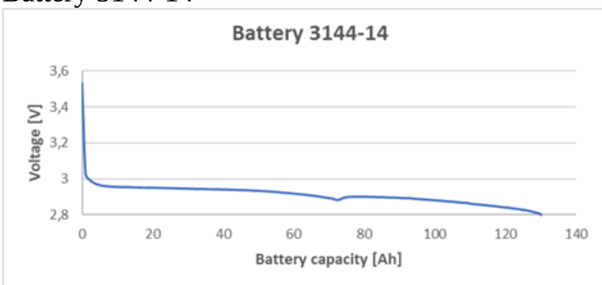

Fig. 9 The course of voltage on the battery 3144-14 at a load of 0.8C, final battery capacity 130.20 Ah

Battery 3144-15

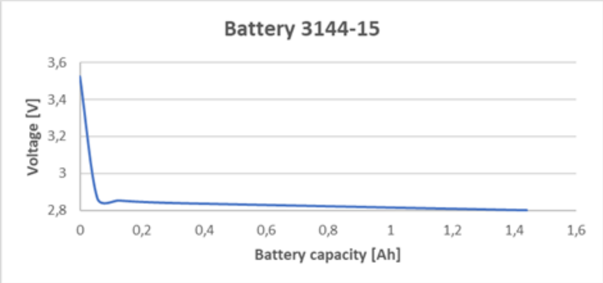

Fig. 10 The course of voltage on the battery 3144-15 at a load of 0.8C, final battery capacity 1.44Ah

Battery 3618-14

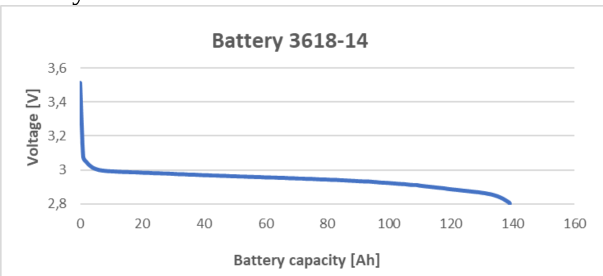

Fig. 11 The course of voltage on the battery 3618-14 at a load of 0.8C, final battery capacity 139.10Ah

Battery 3618-16

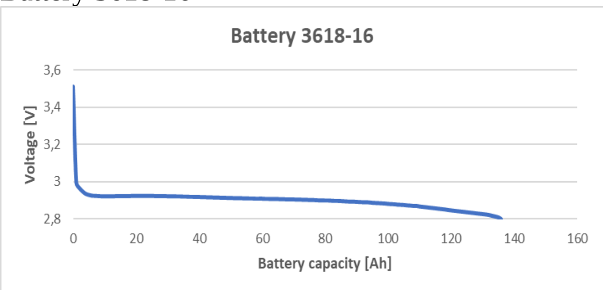

Fig. 12 The course of voltage on battery 3618-16 at load 0.8C, final battery capacity 135.82Ah

Table 3 Table of measured values of battery capacities at different loads and their percentage evaluation

Battery name	3144-14	3144-15	3618-14	3618-16
Capacity of battery, load 0,1C [Ah]	145,57	146,01	148,65	149,62
Capacity from the original capacity [%]	97,05	97,34	99,10	99,75
Decrease in capacity from the original capacity [%]	2,95	2,66	0,90	0,25
Capacity of battery, load 0,4C [Ah]	141,76	141,46	147,38	146
Capacity from the original capacity [%]	94,51	94,31	98,25	97,33
Decrease in capacity from the original capacity [%]	5,49	5,69	1,75	2,67
Capacity of battery, load 0,8C [Ah]	130,2	1,44	139,1	135,82
Capacity from the original capacity [%]	86,80	0,96	92,73	90,55
Decrease in capacity from the original capacity [%]	13,20	99,04	7,27	9,45

We measured a capacity of 145.57Ah for the 3144-14 battery with a load of 0.1C = 15A, which is only 2.95% less than the value of the new battery. At a load of 0.4C = 60A, we measured a value of 141.76Ah, which is 5.49% below the value of the new battery. At a load of 0.8C = 120A, we measured a value of 130.20 Ah, which is 13.20% below the value of the new battery. This battery is still good for use in a vehicle.

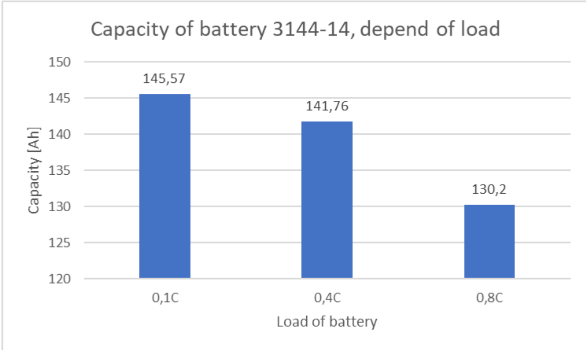

Fig. 13 Description of the measured value of capacities on the battery 3144-14

We measured a capacity of 146.01Ah for the 3144-15 battery with a load of 0.1C = 15A, which is only 2.66% less than the value of the new battery. At a load of 0.4C = 60A, we measured a value of 141.46Ah, which is 5.69% below the value of the new battery. At a load of 0.8C = 120A, we measured a value of 1.44Ah, which is 99.04% below the value of the new battery. This battery cannot be longer used in the vehicle, the 0.8C current is standardly used when operating the vehicle. A 0.8C load revealed a faulty internal grille.

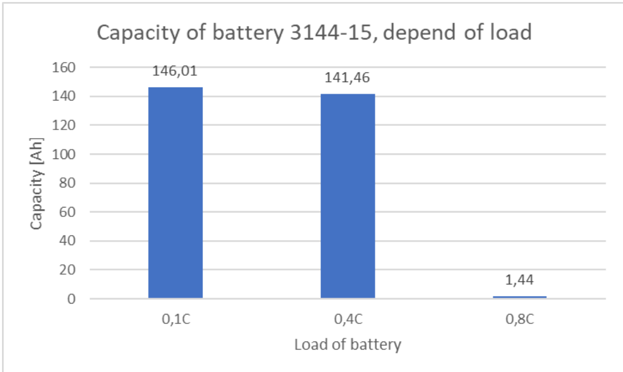

Fig. 14 Description of the measured value of capacities on the battery 3144-15

We measured a capacity of 148.65Ah for the 3618-14 battery with a load of 0.1C = 15A, which is only 0.90% less than the value of the new battery. At a load of 0.4C = 60A, we measured a value of 147.38Ah, which is 1.75% below the value of the new battery. At a load of 0.8C = 120A, we measured a value of 139.1Ah which is 7.27% below the value of a new battery. This battery has small differences from the new battery and it is still good for use in a vehicle.

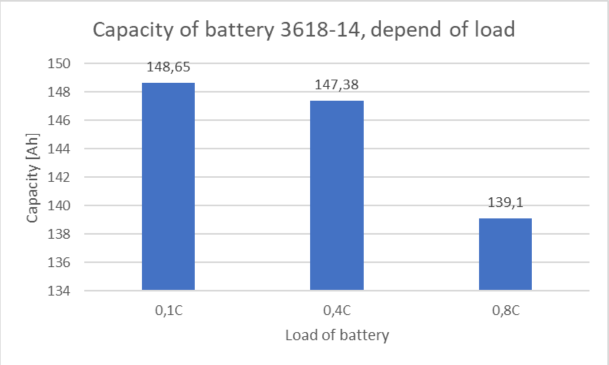

Fig. 15 Description of the measured value of capacities on the battery 3618-14

We measured a capacity of 149.62Ah for the 3618-16 battery with a load of 0.1C = 15A, which is only 0.25% less than the value of the new battery. At a load of 0.4C = 60A, we measured a value of 146.00Ah, which is a value of 2.67% below the value of the new battery. At a load of 0.8C = 120A, we measured a value of 135.92Ah which is 9.45% below the value of a new battery. This battery has small differences from the new battery and it is still good for use in a vehicle.

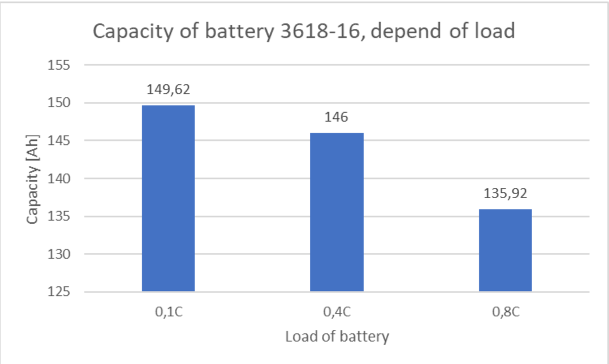

Fig. 16 Description of the measured value of capacities on the battery 3618-16

4 Conclusion

When testing the battery, we found small differences in capacity from 0.25 to 2.95% compared to the value of the new battery when 0.1C (15A in this case) load was applied. These differences did not indicate a problem when using these batteries, if the battery is charged 0.4C, a current of 60A. The differences in the measured capacity are higher from 1.75 to 5.69% compared to the capacity of the new battery. Although the differences in measured capacity are 2.74% higher than the lower load, the batteries are still alright for normal use in the vehicle. When the battery loading is 0.8C with a current of 120A, the differences in the measured capacity are higher from 7.27 to 99.04% compared to the value of the new battery. A difference of 99.04% compared to the new battery capacity means only 0.96% capacity of the original capacity. This difference is very high so we have found a faulty battery which cannot be used longer in the vehicle. The result is that we need to use a minimum load of 0.8C to detect faulty batteries. Perhaps in the future, after measuring multiple batteries, we will find the dependence how to find the faulty battery even at a lower load such as 0.8C, based on multiple measurements and finding new dependencies between the lower load and the faulty battery. Even on our measurement, we can see the highest decrease in measured capacity when loading 0.4C is compared to the new capacity of the battery. The measured decrease of 5.69% on the battery 3144-15 confirmed the damage on the battery when the load was higher.

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