A Novel Jump-start System Based on Reconditioned Li-polymer Batteries

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This paper introduces a method of reconditioning lithium-polymer batteries which are no longer performing as expected. The reconditioning process consists of consecutive charging/discharging steps at controlled currents and is followed by an evaluation procedure, in order to determine the actual performances of the reconditioned batteries. For the evaluation of the characteristics of the Li-polymer batteries, one has measured the charging capacity, the discharging capacity and the internal resistance. However, after the reconditioning stage, one must look for a new application for these batteries, as the reconditioned batteries are seldom behaving as the new ones to be used for the same initial designated application. We manufactured and tested a cold jump-start system, particularly useful in the case of cars flat batteries or cars batteries starting failure. The advantages of this system consist in their reduced mass and volume and a very powerful starting current, comparable to that of high capacity lead acid batteries, the system being able to act as multiple starting aids.

Keywords: Li-polymer batteries, reconditioning, car jump start

The wide use of batteries as energy storage devices and power sources has led to a remarkable development of battery technologies [1]. Among the most used batteries, lithium-based batteries are used in various domains, such as military and aeronautics and they have numerous applications such as portable electronics and miniaturised devices [2]. In this regard, nickel-cadmium (NiCd), nickel-metal hydride (NiMH), lithium-ion (Li-ion), and polymer Li-ion batteries have been developed. However, the progressive energy demands required nowadays set the current trend on finding new devices and continuously improving the already existing ones [1].

One major topic related to the energy storage devices refers to the lithium based batteries, which together with the lead acid batteries [3,4] are one of the most employed batteries in a wide range of domains [5-7], including electrical vehicles [8]. Lithium cells are best employed in such batteries due to the particularity of lithium as element: low atomic mass, high reduction potential, of about -3.04 V, and a high specific charge capacity of lithium cells, of about 3.86 Ah/kg [9].

The most common lithium based batteries are lithium-ion and lithium-polymer (Li-Po) batteries. Studies have proposed few mechanisms for the functioning of these batteries, but the exact mechanism has yet to be perfected [10]. Lithium-polymer batteries have properties similar to lithium-ion batteries and the advantage given by the elimination of the electrolyte leakage so that no protective case is required [2].

Batteries that employ solid polymer electrolytes are considered to possess higher energy density and to be safer to use [11]. Some of the most employed polymers in lithium batteries are polyethylene oxide (PEO), polyvinylidene fluoride (PVdF), polyacrylonitrile (PAN), polymethyl-methacrylate (PMMA) [12], while pure poliethylene electrolytes are known to cause safety problems at high temperatures [13].

In order to properly operate and to prolong the life of a lithium based battery, one should take into account some important factors, such as the charging/discharging procedures applied [14, 15] and the temperature of the batteries during these procedures [16].

One of the charging procedures that have been studied and proposed imply a charging procedure either at constant current, constant-voltage, or constant-current and constant-voltage [8].

The aim of this paper is to propose a reconditioning method for spent Li-polymer batteries, which are no longer able to sustain current for a certain amount of time for their application.

Experimental part

The tested batteries (S1, S2, S3) consist of three rechargeable Li-Po batteries, type T1G6P (TURNIGY POWER SYSTEMS 5.0 ΩMATCHED). The original specification tests provided by the producer stated values of 14.8V for the supplied voltage, 5000mAh for the capacity and 74Wh for energy and the ability to supply a high value current (up to 100 A) for a duration of 30 s.

The analysed systems were used as energy source for *professional mini-racing cars* for about 12-14 months, even though the warranty of the producer was limited to 12 months. These batteries were used for a quick start of the racing mini-cars, that lead to current withdraw of about 30A, but still in parameters prescribed by the producer, that were in the range of 100 to 150 A for 30 s. As their performances decreased in time, they were considered as unfit for the initially intended purpose, where the starting speed and acceleration were of paramount importance, and were destined for recycling, due to their inability to perform at the expected parameters.

A preliminary testing of these units showed low values for both the discharge capacity and the stored energy of about 496 mAh and, respectively, 7.93Wh, far below the 5000 mAh and 74 Wh.

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Moreover, as these batteries are in fact a series of 4 Li-Po cells, one needs a dedicated charger with balancing feature (the battery was provided with a connector of this type by the manufacturer) for balancing the individual charge of each cell and to prevent an uneven charge distributed within the individual cells. This type of charger was employed for all the charging steps for the analysed systems, namely LiPro Balance Charger Imax B6 charger.

Prior to the actual evaluation, the systems were subjected to several charging/discharging stages in order to restore them.

The reconditioning of the systems started with a charging step, performed in two sequences; first, a charging sequence at constant current (2.5A) for 2 h, followed by another charging sequence at constant voltage (17V), up to the point when the value of the charging current dropped under 50mA, which represents 1% of the battery capacity divided by the unit of time, 1 h.

The discharge step was performed with a discharge modulus at a constant current of 1A until the voltage reached a value of 12V.

After each step, the charger provides the following information: the charging/discharging capacity, full charging voltage/cut-off voltage, charging/discharging time and charging/discharging current (the latter was kept constant at 1A for both charging and discharging stages). These values were recorded by the charging/discharging device. The internal resistance of the batteries was measured with an ohmmeter (RIM 100, Voltcraft, Germany), being recorded 5 measurements and then an average of these measurements was calculated.

One of the batteries (S1) was tested from the practical point of view, in order to evaluate the possibility to be used as a cold car jump-start system, meaning that it was discharged at a current of 100A for 10 s with a professional digital battery tester (Voltcraft BT-3, Germany), capable of testing the cold crank shaft current (cca) up to 600A. One has placed a diode on the connecting wires in order to ensure a unidirectional flow, because in practice, there is the possibility of charging the Li-Po battery from the vehicle battery, when starting the engine, the alternator charges the lead-acid battery. In this case, the lead-acid battery being a more powerful battery than the Li-Po one, there is the possibility of a reverse effect and a overcharging of the Li-Po one.

The experimental layout of the cold jump start test carried out is represented in figure 1.

The tested systems behaved normally, by sustaining the required current for 10 S. The discharge current of 100A supplied is enough to jump-start a normal car. After this test, one may see that the electomotive force of the cold jump start system is well above the 14.8 V, namely 15.6 V, enough for carring out further cold jump startings using this system. In order to evaluate how much charge was consumed in this test, S1 battery system was charged once again to the maximum capacity, and then the internal resistance was measured again.

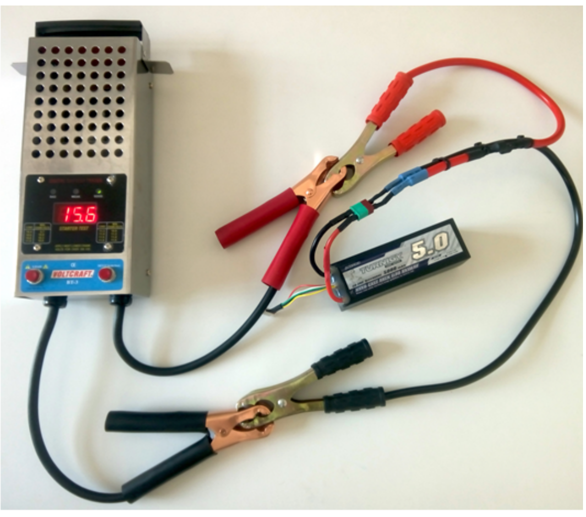

Fig 1. Depiction of the cold jump start test

Results and discussions

The results of the charging/discharging steps are presented in table 1.

Table 1
THE VALUES OF THE CAPACITY AND INTERNAL RESISTANCE FOR THE ANALYZED SYSTEMS

	Q_i, mAh	Q_d, mAh	$R_{i,i}$, mΩ	$R_{i,d}$, mΩ
S1	4839	4563	13.20	13.90
S2	4742	4464	14.70	15.34
S3	5376	4770	14.04	15.98

After this evaluation, the system S1 was subjected to a jump start test, and once again evaluated. The value of the internal resistance recorded after the jump start test was of 13.4 mΩ. After this measurement, the battery was charged up to full capacity, and at the end of the charging step, the charger indicated the value of 404mAh, meaning that the jump start test consumed only 404mAh in one go from the total capacity of the battery.

Comparing the value of the internal resistance of the battery after the first cold jump start with the previous, one may notice just a very small increase of its value from 13.2 up to 13.4, which represents cca. 1.5%. This entitles us to say that this device may be successfully used for more than one single jump star test. This is a real advantage, as one is not force to recharge the system after every single jump start. On the other hand, one may calculate, a virtual short-circuit current (I_{sh}) for this system, its physical meaning being that of a maximum current value when the terminals are put in short-circuit, action totally forbidden and considered dangerous from the practical point of view. This is the reason why this is a virtual representation of the maximum current that the system can produce (when the external resistance tends to be 0).

The short-circuit current can be calculated using equation 1:

$$I_{sh} = \frac{14.8}{R_{i,i}} \quad (1)$$

In the case of system S1, the value of I_{Sh} is 112 A, meaning that this system could be safely used at 110% from the tested value, which represents a value of 110 A for 10 seconds. By calculating the total charge consumed during the cold jump-start taken at maximum current for 10 seconds, it results a total consumed capacity of 0.305Ah, which is less than 6.1% of the battery capacity. This means that the system can be used for at least 8 jump starts of 10 seconds, each supplying a current of at least 110A up to the point when the system will be 50% discharged.

Conclusions

Some lithium-polymer batteries no longer in their working parameters have been reconditioned by consecutive charging/discharging steps and subsequently evaluated. The evaluation procedure consists in measuring the charging and discharging capacity and the internal resistance.

After the reconditioning and evaluation steps, the batteries were successfully tested in order to use them as cold jump start systems for the batteries employed for vehicles.

References

1. GANDOLFO, D., BRANDAO, A., PATINO, D., MOLINA, M., J Energy Inst., **88**, 2015, p. 470-479;
2. BADEA, T., NICOLA, M., VAIREANU, D.I., MAIOR, I., COJOCARU, A., Electrochimie si Coroziune, Ed. MATRIX ROM, Bucharest, 2005, p.231;
3. BUZATU, T., GHICA, V.G., Rev. Chim.(Bucharest), **64**, no. 2, 2013, p. 170
4. BUZATU, T., BADANOIU, G., GHICA, V.G., BUZATU, M., Rev. Chim.(Bucharest), **66**, no. 8, 2015, p.1147
5. CERAOLO, M., LUTZEMBERGER, G., POLI, D., Journal Storage Mater., **11**, 2017, p. 211-218;
6. ZHENG, L., ZHANG, L., ZHU, J., WANG, G., JIANG, J., Appl. Energy, **180**, 2016, p. 424-434;
7. DENG, Z., YANG, L., CAI, Y., DENG, H., SUN, L., Energy, **112**, 2016, p. 469-480;
8. ZHIFU, W., YUPU, W., ZHI, L., QIANG, S., YINAN, R., Energy Procedia, **104**, 2016, p.74-79;
9. SERGI, F., ARISTA, A., AGNELLO, G., FERRARO, M., ANDALORO, L., ANTONUCCI, V., J. Storage Mater., **8**, 2016, p. 235-243;
10. COJOCARU, A., MAIOR, I., CAPRARESCU, S., CIOBOTARU, I.A., VAIREANU, D.I., Electrochimia aplicata in ingineria economica, Ed. Electra, 2015, Bucharest, p. 206, ISBN: 978-606-507-081-3;
11. SUN, C., LIU, J., GONG, Y., WILKINSON, D.P., ZHANG, J., Nano Energy, **33**, 2017, p. 363-386;
12. LI, Q., CHEN, J., FAN, L., KONG, X., LU, Y., Green Energy Environ., **1**, 2016, p.18-42;
13. KRITZER, P., J. Power Sources, **161**, 2006, p. 1335-1340.
14. LINDGREN, J., LUND, P.D., J. Power Sources, **328**, 2016, p. 37-45;
15. ASHWIN, T.R., CHUNG, Y.M., WANG, J., J. Power Sources, **328**, 2016, p. 586-598;
16. WANG, Q., JIANG, B., LI, B., YAN, Y, Renewable and Sustainable Energy Rev., **64**, 2016, p. 106-128.

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