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The REIMEI Li-ion Batteries after more than 12 years of Operation

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Abstract

The satellite 'REIMEI' was launched in August 2005; this satellite is one of the first spacecraft to use Li-ion batteries. The orbit of the satellite is a low earth orbit, over 65000 charge/discharge cycles have been reached and REIMEI is still operating. We are trying to estimate the remaining useful capacity and state of health for the REIMEI Li-ion batteries. However, the estimation of remaining useful life for Li-ion cells is not trivial, since their degradation is caused by many physical and chemical processes which get accelerated depending on the working environment and operating conditions. The satellite uses 2 batteries, each battery consists of 7 cells. The cells use $LiMn_2O_4$ and graphite as the positive and negative electro-active materials, respectively. The rated capacity of each cell is 3 Ah. In this work we analyse the performance of the REIMEI batteries based on telemetry data.

Keywords: Lithium-ion-battery, End of Discharge Voltage, telemetry data

Abbreviations

SOC	State of charge
EoDV	End of discharge voltage
CC	Constant current
CV	Constant voltage
LEO	Low earth orbit
DoD	Depth of discharge

1. Introduction

Energy storage devices are an essential part of the power system for satellites, rockets and spacecraft. Li-ion cells have become the first choice to power aerospace applications, since they have a high energy density and a coulombic efficiency close to one [1-4]. Li-ion cells possess a high energy density but can cause catastrophic incidents when they are not properly managed or diagnosed, and this could end up costly missions [5, 6]. However, the diagnosis and state estimation of Li-ion cells is not trivial, since many degradation processes take place and these depend on the cells operating conditions, such as temperature and state of charge (SOC) [7].

In this work we analyse the battery telemetry data of the REIMEI satellite. REIMEI was launched in 2005, and it is one the first satellites to use Li-ion batteries. REIMEI is a piggy-back satellite which was designed and developed at the Institute of Space and Astronautical Science (ISAS) [8, 9]. The mission of REIMEI was to do aurora observations by using three cameras with different wave length filters.

2. Material and methods

2.1 Li-ion cell

The REIMEI battery consists of pouch Li-ion cells with a rated capacity of 3 Ah manufactured by NEC-Tokin Corporation. The cells use $Li_xMn_2O_4$ as cathode active material and graphitized carbon as anode active material. The electrolyte composition is 1M of $LiPF_6$ EC/DEC (3:7 by wt%).

2.2 Li-ion battery

The flight battery consists of two strings connected in parallel. Each string has seven cells connected in series. The Li-ion cells were potted with epoxy resin.

2.3 Battery operation

The Li-ion battery is charged and discharged according to a LEO profile operation. One cycle comprises of 60 min charge time and 35 min discharge time. During charge, a constant current-constant voltage (CC-CV) process is used. Here, a depth of discharge (DoD) is usually maintained at 20%.

4. Results

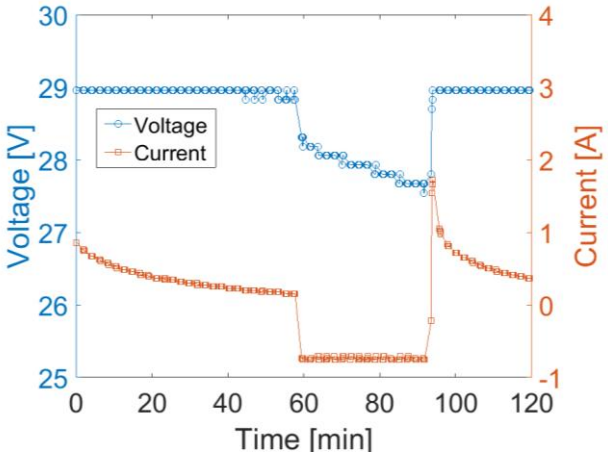

Fig. 1. Telemetry data of the REIMEI battery 1 obtained on September 5th, 2005.

Figure 1 shows the voltage and current profiles of the REIMEI battery 1 obtained from telemetry data. Here, the charging and discharging profiles for voltage and current can be observed.

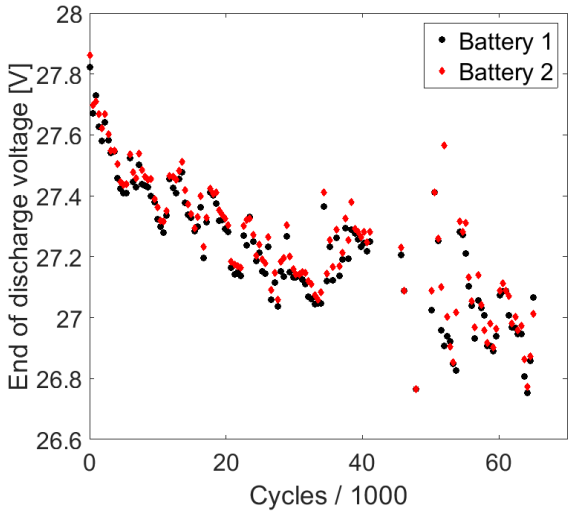

Fig. 2 End of discharge voltage of REIMEI battery 1 (black) and battery 2 (red).

Figure 2 shows the trend for the end of discharge voltage of the REIMEI batteries as a function of charge-discharge cycles.

6. Conclusions

Telemetry data of the REIMEI Li-ion batteries is examined based on the end of discharge voltage trend through charge-discharge cycles. In future work, we will try to estimate the state of health for the batteries based on the end of discharge voltage trend from experimental data and simulation results.

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