Gregor Glanz[1,2*]// Markus Koller[1,2]// Katja Fröhlich[1] // Marcus Jahn[1]
1) AIT Austrian Institute of Technology GmbH, Center for Low-Emission Transport, Electric Vehicle Technologies, Giefinggasse 2, 1210 Vienna, Austria.
2) Graz University of Technology, Institute of Electrical Measurement and Sensor Systems
*corresponding author: gregor.glanz@ait.ac.at

IN OPERANDO DETERMINATION OF THE HOMOGENEOUS YOUNG'S MODULUS OF A LITHIUM-ION BATTERY POUCH CELL

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TOMORROW TODAY

INTRODUCTION

In this study the homogeneous Young's modulus (YM) of a Lithium-Ion battery (LIB) pouch cell is determined with a novel non-destructive experimental setup. The YM is an important material parameter, necessary to perform simulations and calculations regarding the deformation and therefore estimate possible safety threats of LIBs. The change of the mechanical properties, including the YM, is caused by the intercalation and deintercalation of lithium-ions in the electrodes while charging and discharging [1].

- Test set-up: two-point bending test, where the LIB pouch cell is clamped on one side using springs, shown in Fig. 1.
- Deflection caused by different weights is measured with a triangulation sensor → homogeneous YM of a LIB can be calculated.
- FEM-Simulation depicting the two-point bending test setup using the obtained values of the homogeneous YM was carried out

CALCULATING THE HOMOGENOUS YM FROM DEFLECTION MEASUREMENTS

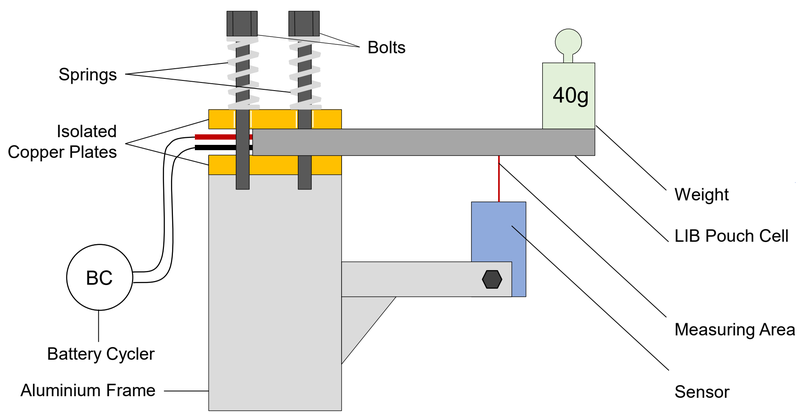

Fig. 1: Functional diagram of the test set-up

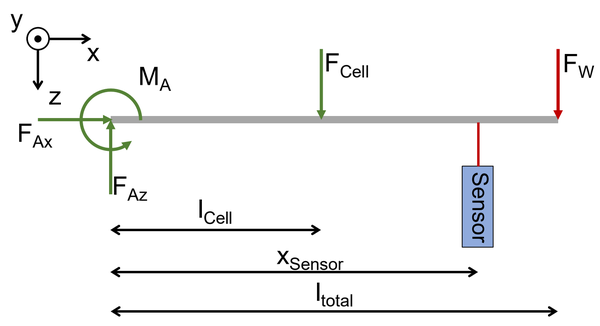

Fig. 2: Diagram of the forces and loads resulting on the LIB

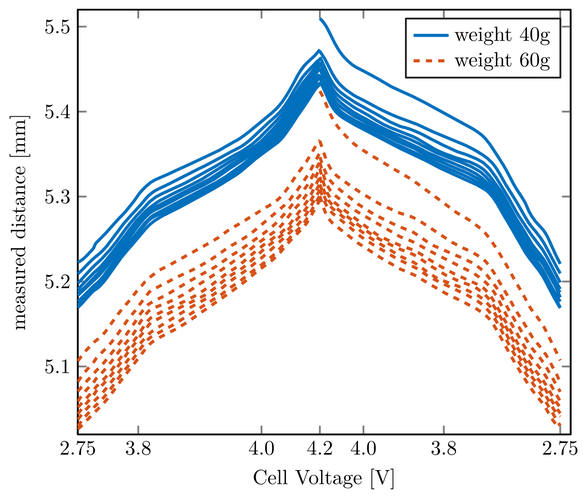

Fig. 3: Measured distance using two different weights over multiple cycles at 0.05C.

With using Newtonian mechanics, the resulting forces on a LIB can be derived, as seen in Fig. 2.
With the linear elasticity theory and the boundary conditions of a cantilever beam the differential equation can be solved for the homogeneous YM (Eq .1).
Various cycles have been performed and the deflection was constantly measured, (Fig. 3).

The calculated mean homogeneous YM can be seen in Fig. 4 for different C-rates:

- **9 cycles** for each C-rate have been performed, **deflection differs between each cycle**.
- **Higher** values of the homogeneous YM **for 0.5C than for 0.05C.**
- Homogeneous YM is **dependent on C-rate** and **charging/discharging-cycle**.
- Values vary between **625-725 N·mm^{-2}** and **895-1019 N·mm^{-2}**.

Eq. 1: Calculating the homogeneous YM of a LIB:

$$E = \frac{F_W}{6\,J\,\Delta d}\,(3\,l_{total}\,x^2 - x^3)$$

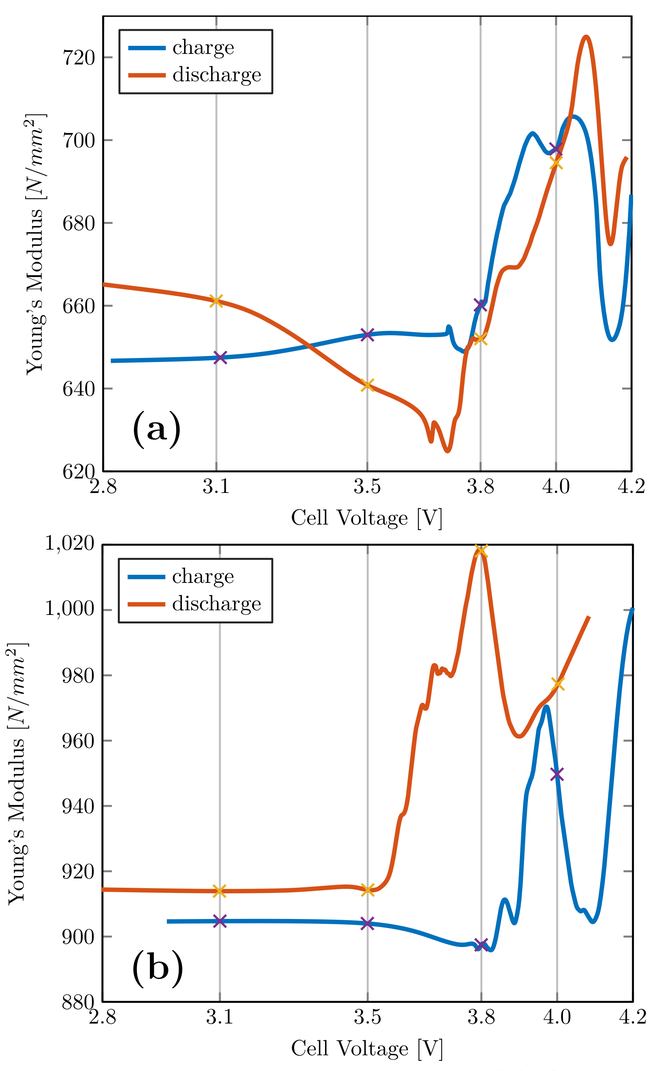

Fig. 4: Mean homogeneous YM for 0.05C (a) and 0.5C (b) with marked YM-values for certain cell voltages which are used for FEM-simulation

FEM-SIMULATION AND VALIDATION

To validate the measured homogeneous YM a FEM-simulation which depicts the two-point bending test setup (Fig. 5) was carried out.

- Deflection for two different C-rates simulated.
- **8 simulation at different cell voltages** for each of the two different weights were carried out
- Good agreement between measured and simulated deflection for several cell voltage levels, see Fig. 6.

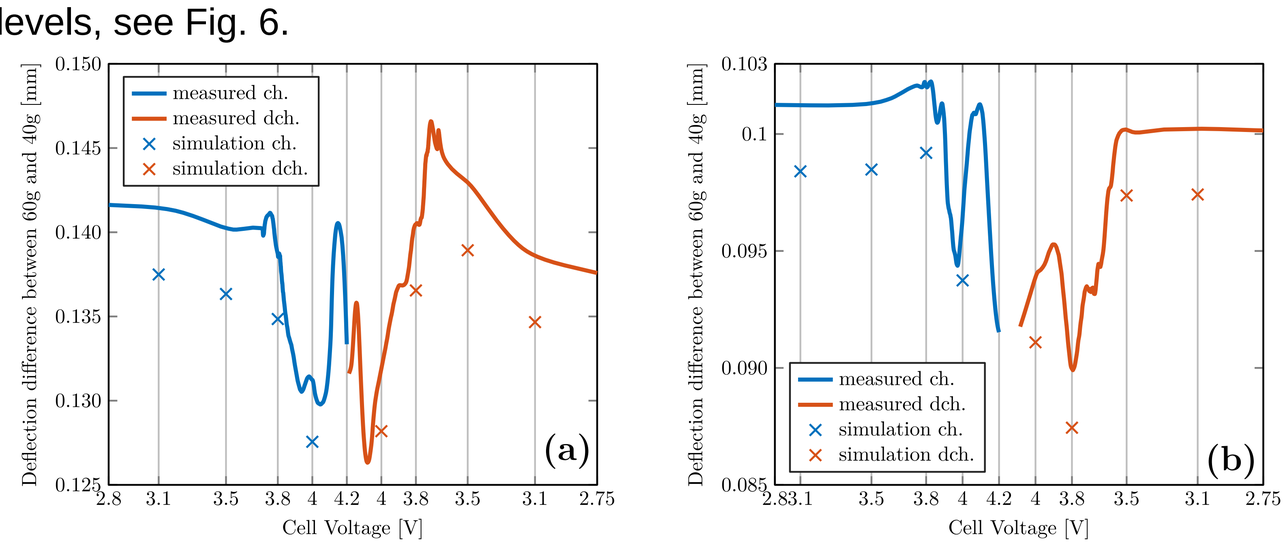

Fig. 6: Measured and simulated deflection for two different weights and two different C-rates, 0.05C (a), 0.5C (b). Using the obtained values for the homogeneous YM from Fig. 4 and a Poisson's ratio of 0.30 for the simulation.

FUTURE STEPS AND OUTLOOK

- **Different C-rates**
- Simulations with **varying** the **Poisson's ratio**
- Investigating a possible **temperature dependency**
- How does the **ageing behavior** of the LIB-pouch cell influence the homogeneous YM

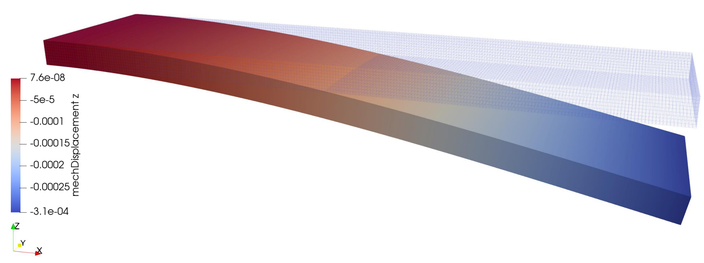

Fig. 5: FEM-Simulation model of the two-point bending test using the software openCFS, visualized in ParaView. (Displacement amplified by the factor 100.)

[1] H.Popp, M. Koller, S. Keller, G. Glanz, R. Klambauer, A. Bergmann. State Estimation Approach of Lithium-Ion Batteries by Simplified Ultrasonic Time-of-Flight Measurement. IEEE Access, 7:170992–171000, 2019

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