Effects of vibrations and shocks in electric vehicles on Li-ion batteries

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Scope of investigations

Effects of vibrations and shocks in electric vehicles on Li-ion batteries

e-bikes, electric motorcycles and scooters, HEV, PHEV, FCEV, BEV

Two cell types investigated:
- pouch (0.7 Ah)
- 18650 (1.95 Ah)
Effects of vibrations and shocks in electric vehicles on Li-ion batteries

For each load profile:
- 2 cells in y-direction
- 2 cells in z-direction
- 2 references
Vibration test acc. to UN 38.3 T3

- UN 38.3: standard for transport of lithium cells
- Logarithmic sine sweep: Freq. range: 7 Hz – 200 Hz – 7 Hz
  Duration: 12 times → 3 h
Vibration test acc. to UN 38.3 T3

Test setup:  
- Displacement profile programmed in Matlab
- Electro-dynamic shaker LDS V406
- Measurement of profile with acceleration sensors
Vibration test acc. to UN 38.3 T3

I. Results – Electrical check-up:
Electrochemical Impedance Spectroscopy (EIS)
No degradation
Vibration test acc. to UN 38.3 T3

I. Results – Electrical check-up:
   No degradation

II. Results – Micro-X-ray computed tomography

III. Results – Post-mortem analyses:
   Loose mandrel when cells were opened and disassembled
Shock test acc. to UN 38.3 T4

- Half sine shock in 6 ms with 150 g
- Shaker (AVEX SM – 100) powered by compressed air with elastomeric shock pad
Shock test acc. to UN 38.3 T4

I. Results – Electrical check-up:
No degradation

II. Results – μCT
Pouch cells and 18650 cells shaken in y-direction: No deg.
18650 cells shaken in z-direction:

Loose mandrel struck against cell‘s internal components → CID deactivated & electrical tab deformed
Real-world long term vibrational test

Desired load profile:

- Freq. range: 4 Hz – 20 Hz – 4 Hz
- Max. RMS-Acceleration: 1.9 g
Real-world long term vibrational test

Implemented (and measured) load profile

Self-developed shaker based on eccentric wheel propelled by stepper motor with max. 2200 rpm
I. Results – Electrical check-up:

Pouch cells and 18650 cells shaken in y-direction: No deg.
18650 cells shaken in z-direction: Higher impedance
Real-world long term vibrational test

I. Results – Electrical check-up:
Pouch cells and 18650 cells shaken in y-direction: No deg.
18650 cells shaken in z-direction: Higher impedance

II. Results – μCT and disassembling
Pouch cells and 18650 cells shaken in y-direction: No deg.
18650 cells shaken in z-direction:

Loose mandrel struck against cell’s internal components
→ Hole punched in negative current collector
Real-world long term vibrational test

I. Results – Electrical check-up:
Pouch cells and 18650 cells shaken in y-direction: No deg. 18650 cells shaken in z-direction: Higher impedance

II. Results – μCT and disassembling
Pouch cells and 18650 cells shaken in y-direction: No deg. 18650 cells shaken in z-direction: Hole in current collector

III. Results – Scanning electron microscopy
18650 cells shaken in z-direction: Micro short circuits
Conclusion

- Vibrations and shocks can lead to degradation and failure for Li-ion cells.
- Standard tests and real-world loads have different effects on Li-ion cells.
- Cell might pass standard tests although (safety) features failed.
- Mechanical design of a cell and its internal components decides whether a cell withstands vibrations and shocks or fails.

Results of tested 18650 cells not directly transferable to all 18650 or hard casing cells.
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