Zwick / Roell

Intelligent Testing

Mechanical Testing Solutions for Lithium-Ion batteries in Automotive applications

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testXpo 2017

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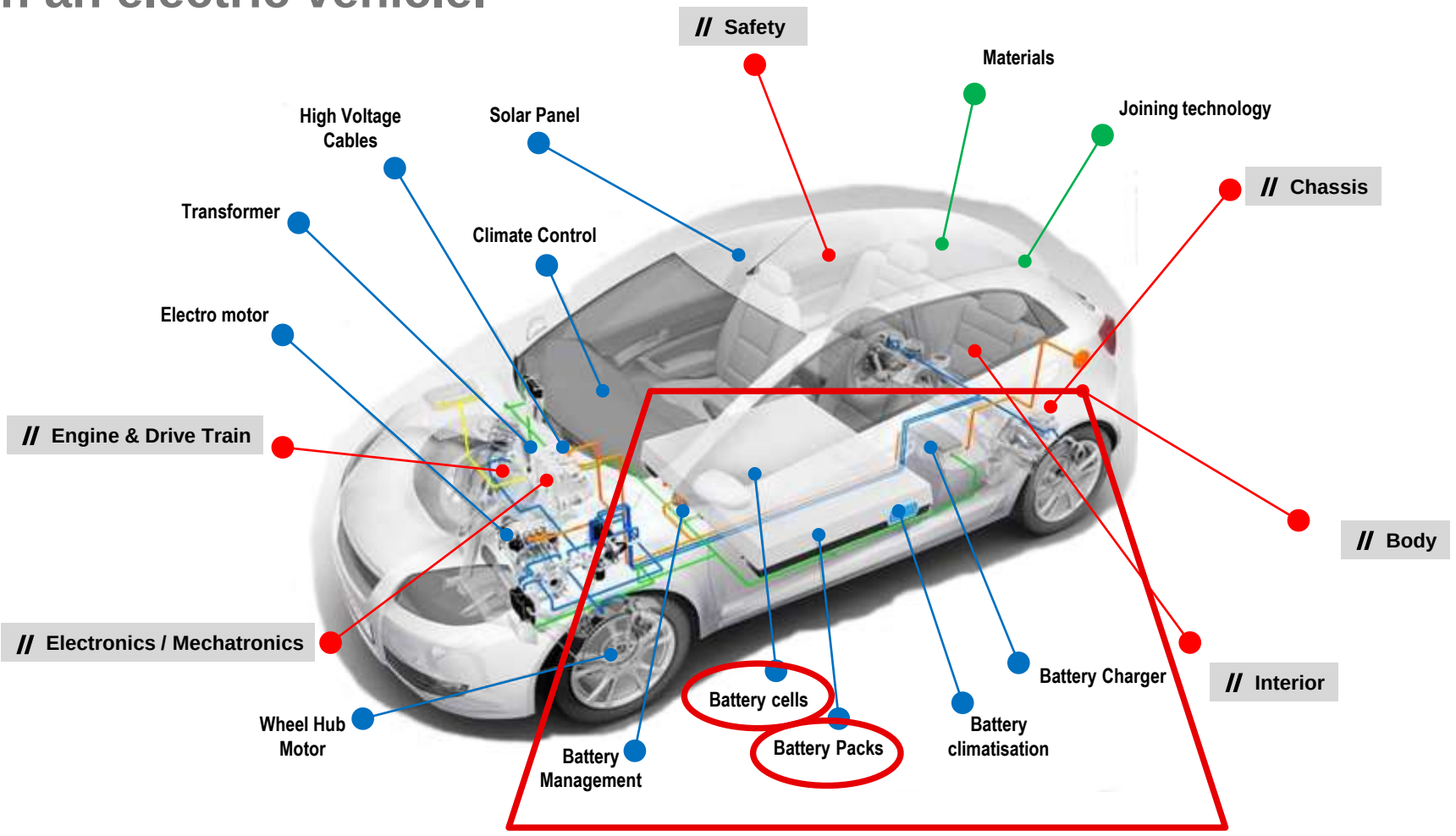
Battery usage in automotive applications

Lithium-ion batteries are used as the main rechargeable energy source in electrical vehicles.

New components in E-Cars

The battery system and its components are the key elements in an electric vehicle.



Battery system components

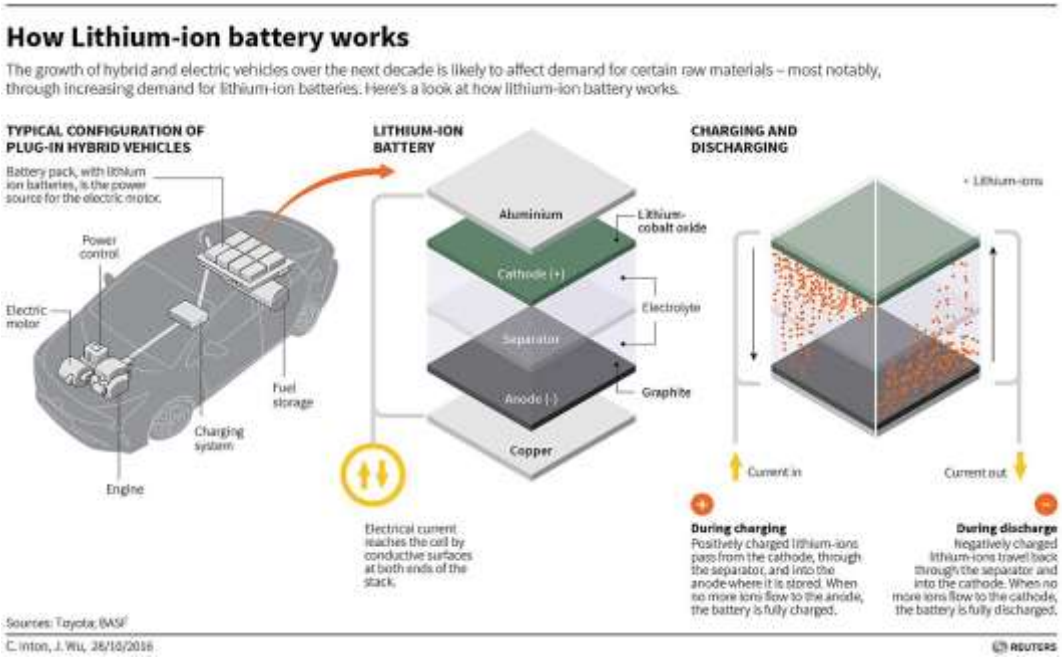
Battery systems are playing an important role in the performance of electric vehicles.

Battery system components

Traction battery systems are typically made of cells which are combined in modules. Additionally the systems require structural enclosures, management electronics, cabling and cooling.

Working principle of a Lithium-ion battery

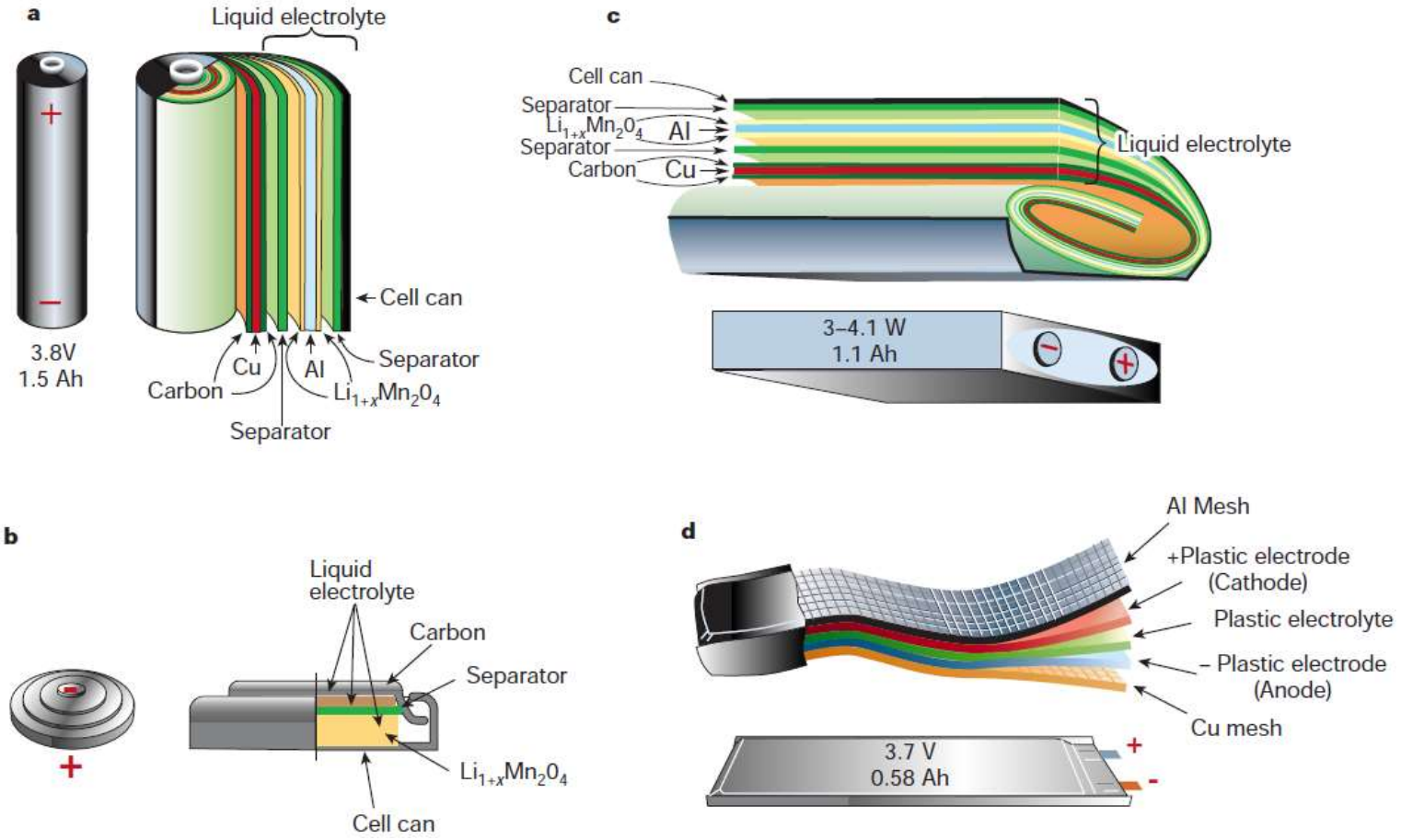
Lithium-ion batteries are highly efficient energy storage devices which allowed modern electric vehicles to become an alternative mobility solution.



- Cell components:
  - Positive electrode (cathode) typically LiCoO2 or LiFePO4 – coated aluminum
  - Separator (polymer-film)
  - Negative electrode (anode) typically graphite-coated copper
  - Electrolyte
- During charging lithium-ions move from the positive electrode to the negative electrode
  -> energy is stored
- During discharge lithium-ions move back from the negative electrode to the positive electrode
  -> energy is released

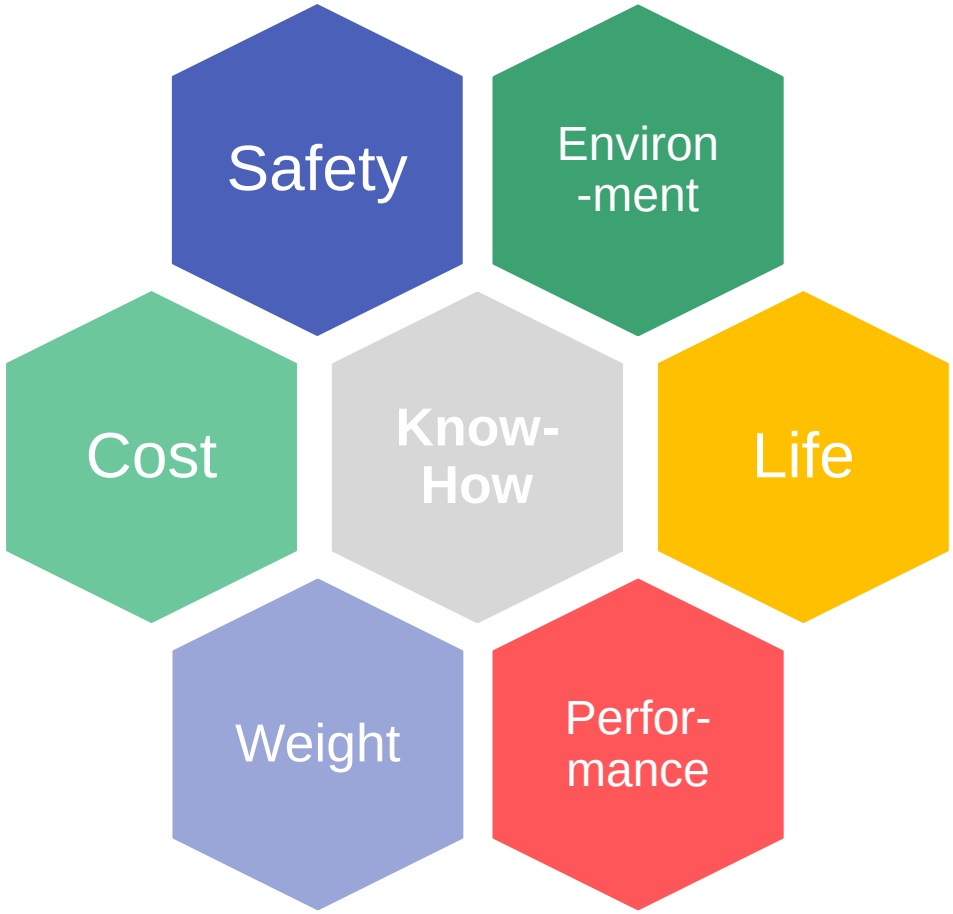
Types of lithium-ion battery cells

Lithium-ion battery cells come in different sizes and shapes. Batteries for electrical vehicles are bigger and store much more energy.



Design objectives for lithium-ion batteries

There is a lot of effort going into the improvement of the batteries and the search for the best compromise. Testing is crucial for R&D as well as quality control.



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Testing of lithium-ion batteries

A wide range of tests is performed on high power lithium-ion batteries for electrical vehicles.

- Types of tests:
  - Incoming material inspection
  - Electrical characterization *
  - Ageing tests *
  - Safety tests (*)
  - Environmental tests
  - Abuse tests (*)
- Typical standards:
  - UN ECE 100 – R2
  - ISO 12405 - 1, 2, 3
  - SAND2005 – 3123
  - VW PV 8450
  - …

Overview of typical abuse tests:

Nr.	Test	Result
1	Controlled Crush	✓
2	Penetration	✓
3	Drop	✓
4	Immersion	✓
5	Roll-over Simulation	✓
6	Mechanical Shock	✓
7	Thermal Stability	✓
8	Simulated Fuel Fire	✓
9	Elevated Temperature Storage	✓
10	Rapid Charge / Discharge	✓
11	Thermal Shock Cycling	✓
12	Overcharge / Overvoltage	✓
13	Short Circuit	✓
14	Overdischarge / Voltage	✓
15	Partial Short Circuit	✓

* not or partially in Zwick Roell portfolio

Mechanical tests on battery cells

An electric-vehicle battery (EVB) is a high energy device that requires considerable precaution for testing to prevent an uncontrolled fire (thermal runaway).

- Various factors can influence the risk of a short circuit and a „thermal runaway“:
  - State of charge (SOC)
  - Chemical composition
  - Mechanical damage
  - Material quality
  - Manufacturing quality
  - Temperature
  - Vibration
  - Design
  - …

- **Risk for operators and/or equipment has to be limited by:**
  - **Isolating these critical tests in especially explosion protected rooms**
  - **Using special temperature chambers which add an additional protection**
  - **Ideally a combination of both**

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Design objective for battery impact protection

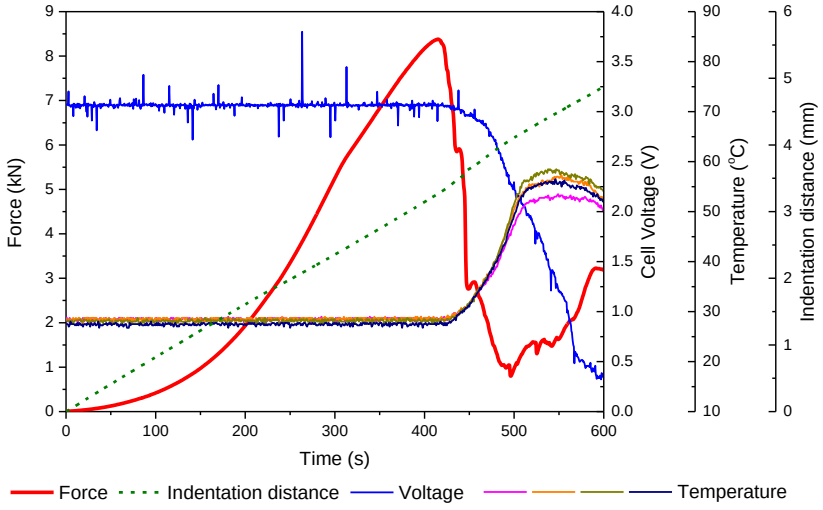
Design goal for **no-fire** should be minimizing risk of short circuit while tolerating certain level of deformation

Impact deformation
→ Damage
→ Short circuit
→ Heat accumulation
→ Thermal runaway (fire)

Li-ion battery – Cell integrity

Characterizing and modeling failures of battery materials and short circuit of battery cells

- ✓ indentation increase
- ✓ force peak
- ✓ voltage drop
- ✓ temperature rise



Luo, Jiang, Xia, Zhou. Fracture mode analysis of lithium-ion battery under mechanical loading. 2015 ASME Congress. IMECE2015-52595.

Li-ion battery – Cell materials

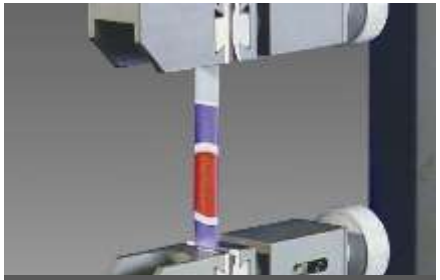
Highly automated production processes require a good understanding of material characteristics

- Components/layers of battery cells:
  - Coated and uncoated plastic films (anode, cathode, separators, enclosure)
  - Coating quality (Graphite, Lithium Cobalt Oxide)
  - Aluminum, Copper foil
  - Electrolyte (liquid/solid)
  - Connectors, weld tabs,…

- Tests are performed under various environmental conditions, i.e.
  - Temperature (e.g. -40°/+100°C)
  - Humidity
  - Chemical influence
  - Mechanical damage
  - Etc…

Li-ion battery – Cell materials

Various standard testing solutions fulfill the requirements for better characterization of battery cell components


Tensile


Puncture


2-point flexure

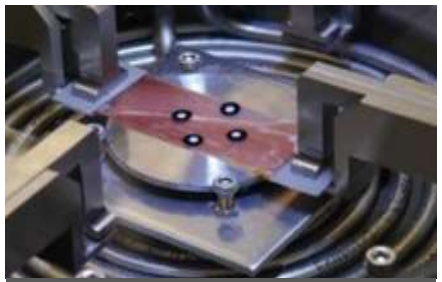

Peel testing


Friction


Horizontal tensile


Tensile creep in bath

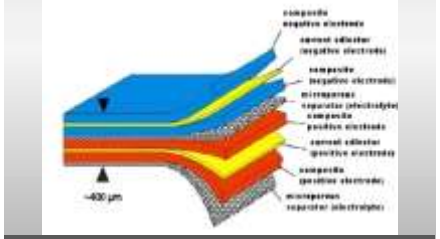

90° Peel / Delamination


Bi-axial test in bath


Automation

Testing surface coating adhesion (Graphite and lithium cobalt oxide) on anodes and cathodes of lithium-ion cells

Z-direction tensile test on cathode coating



Li-Ion battery cell layers

Description:

determine the surface adhesion forces of electrode coating

Zwick solution:

- Machine: Z010 Allround-Line with testControl II electronics
- Fast (2000 Hz) synchronous measured-value acquisition
- Special Z-direction tensile fixture to measure adhesion forces
- High repeatability and throughput due to up to 5 tests in one setup

Li-ion battery – Cell integrity

Battery cells as smallest energy source entity need to satisfy a number safety critical tests, especially under abuse conditions

- Mechanical tests at different states of charge and environmental conditions:
  - Tensile, Torsion, (Static and Fatigue)
  - 3-/4-point bending (Static and Fatigue)
  - SOC Inflation/Deformation
  - Forced short-circuit (Nail penetration test)
  - Crush
  - Drop *
  - Impact
  - …

* not in Zwick Roell portfolio

Li-ion battery – Cell integrity

Examples of mechanical tests on lithium-ion pouch cells

Nail penetration / Impact

Puncture

Flat crush

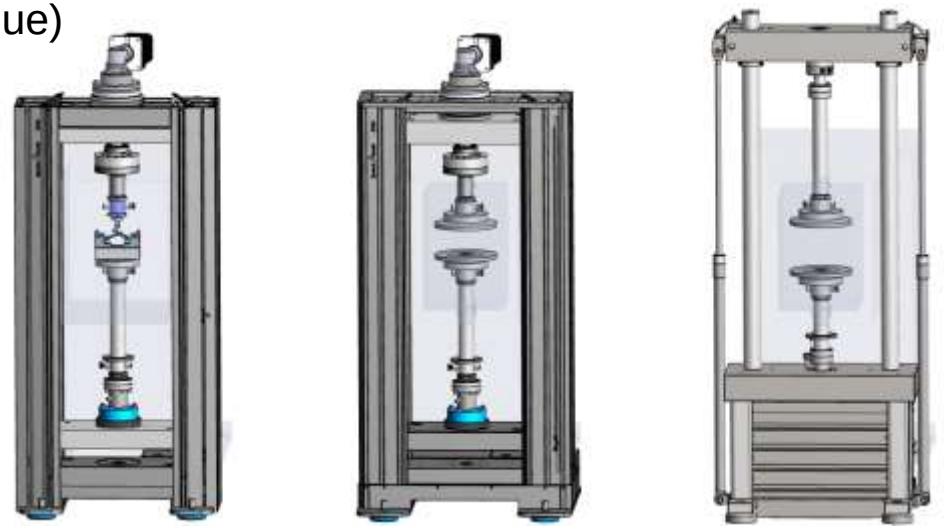
Edge crush

*Cardboard sample in place of pouch cell

Li-ion battery – Cell research

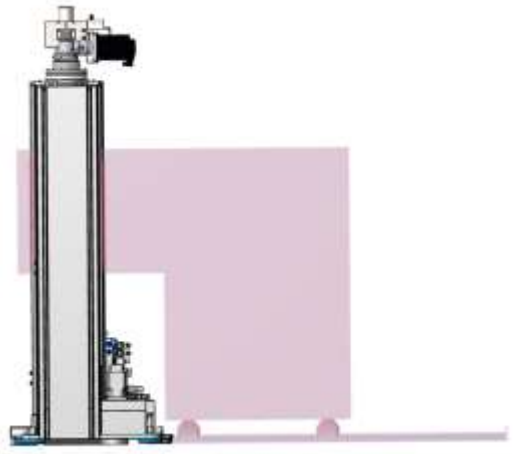
Example of a test configuration for advanced material research on lithium-ion and future technology battery cells

- Research objective:
  - R&D on new materials for high energy battery cells
- Types of test:
  - Tension, Flexure, Torsion (static and fatigue)
  - Temperature
- Equipment:
  - 2x Tension-Torsion (100 + 250 kN)
  - 1x Fatigue loadframe (100 kN)
  - 3x Temperature chamber (EUCAR 6)
  - Special tooling for future cell design
  - Integrated with room safety equipment



Mechanical tests on battery cells

Special temperature chambers (EUCAR 6) protect operators and testing equipment.



Universal Testing Machine equipped with safety temperature chamber

Li-ion battery – Modules

Battery modules are comprised of several battery cells. The integrity of the module is of high importance.

- Battery modules/packs:
  - Mechanical enclosure (Aluminum, Sheet metal, Plastics)
  - Cabling
  - Cooling
  - Connectors
- Tests:
  - Shock / Impact
  - Crush
  - Environmental
  - Structural
  - Abuse (*)
  - Vibration *
  - Electrical performance *

* not in Zwick Roell portfolio

Li-ion battery – System

Entire battery systems are typically tested for their performance in a vehicle in various conditions

- Entire battery systems:
  - Mechanical enclosure (Aluminum, Sheet metal, Plastics)
  - Cabling
  - Cooling
  - Connectors
- Tests:
  - Shock tests
  - Vibration tests
  - Environmental tests
  - Structural tests

Contents

Testing solutions

Through constant innovation, we offer all components necessary for professional material testing.

// Static testing machines

// Fatigue testing machines

// Hardness testers

// Software testXpert® III

// Electronics

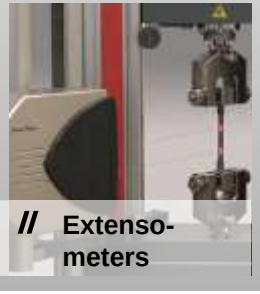
// Impact Testers

// Plastometers

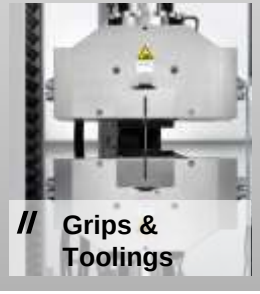
// HDT-Vicat

// Sheet metal testing

// Robotic testing

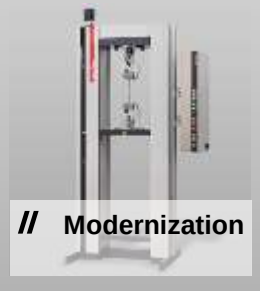


// Extenso-meters

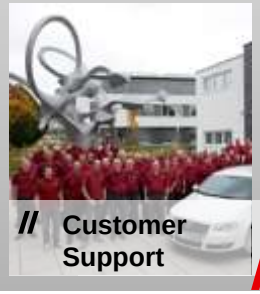


// Grips & Toolings

// Load Cells



// Modernization



// Customer Support

DIRECT LINKS: // Innovations // testXpo in Ulm // What is testing? // SAFETY // Reliable Test Results