





excellence in ...

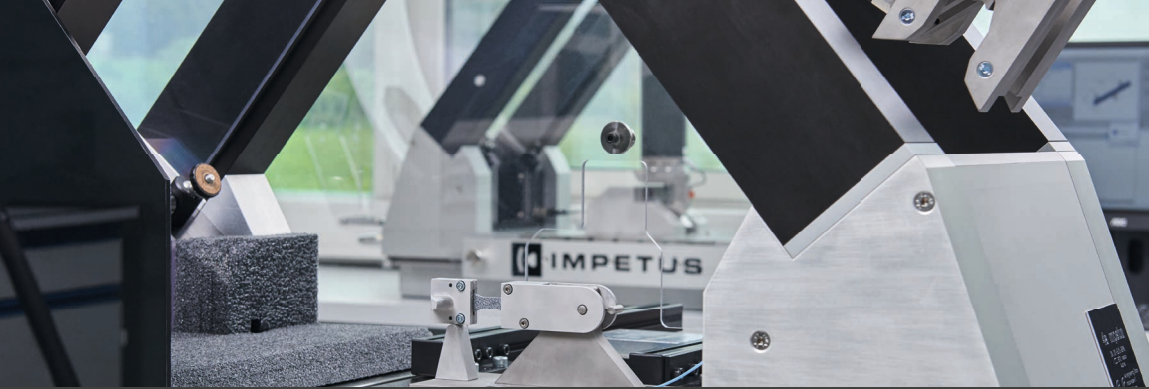
plastics simulation
testing equipment
lightweight products
battery testing

We are a technically oriented research and development company specialized in testing and simulation solutions for material engineering and battery applications.

4a engineering develops testing hard- and software and performs material characterization for finite element simulations, abuse testing of battery cells and cell stacks and generates corresponding simulation models. One of our specialities is the generation of validated material cards for vehicle crash applications, which is proven by many OEMs worldwide. In addition, we have gained considerable experience in the application of complex material models, as well as the development of new material models and simulation methods.



I N P H Y S I C S W E T R U S T



I N P H Y S I C S W E T R U S T



IMPETUS

efficient dynamic testing

What is it good for?

- ✓ desktop testing device for dynamic characterization
- ✓ efficient and economic stand alone solution
- ✓ for polymeric materials, composites, foams and light metals
- ✓ fully automated material card generation with VALIMAT®

Your convenient way of generating material data

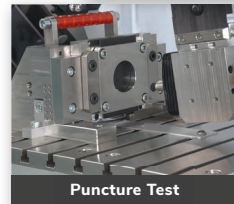
- ✓ velocities up to 4.5 mps
- ✓ energies up to 50 J
- ✓ interface for evaluation and storage of test data
- ✓ no prerequisites for installation necessary

Adjustable for all needs

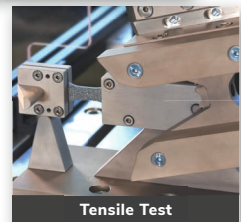
- ✓ various accessories i.e.: insulation magazine, DIC cameras...
- ✓ variety of test setups for rapid reconfiguration



3 Point Bending Test



Puncture Test



Tensile Test



LINOVIS
high performance modular testing

What is it good for?

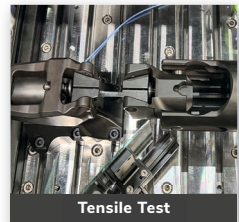
- ✓ all purpose high fidelity testing machine for material characterization
- ✓ up to 4 industry-standard-machines in one
- ✓ highest force and speed range of all available electro-dynamic machines
- ✓ seamless 3D DIC integration
- ✓ prepared for automated test execution and change of test setups

Key Specs

- ✓ max. force: 25 kN
- ✓ max. speed: 3.2 m/s
- ✓ energy: 600 J

Characterization of a wide range of materials

- ✓ static / dynamic / cyclic loading conditions
- ✓ steel / light metal / composites / plastics / adhesives



Tensile Test



Moveable Control Unit



Highspeed DIC



HERCULES
high performance battery testing

What is it good for?

- ✓ Thermal runaway and propagation testing of battery cells, cell stacks and modules
- ✓ controlled and safe environment

Safety Features

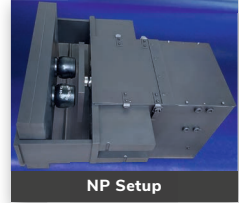
- ✓ overpressure valves / SPS safety circuits / inertization inlets
- ✓ controlled pressure release / extraction hood & bypass

Test Modes and Advanced Analysis Capabilities

- ✓ Open mode with continuous gas extraction
- ✓ Closed mode with defined O₂ concentration
- ✓ Fully inertized mode (e.g., nitrogen atmosphere)
- ✓ Gas chromatography for precise gas analysis during tests
- ✓ ARC-like testing simulates extreme conditions to assess safety



Gas Chromatography



NP Setup



Safety Test Environment

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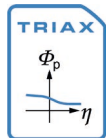
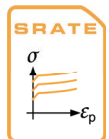
MATERIAL cards

Validated material cards ready to use for your crash simulation

- ✓ from raw material to validated material card
- ✓ standardized packages for a variety of materials
- ✓ short lead times and high accuracy due to highly automated process
- ✓ recommendation of package choice based on intended application

Simple deformation or fully triaxiality dependent material cards

- ✓ industry standard solvers (LS-Dyna®, Pam-Crash®, Abaqus®) and material models
- ✓ comprehensive static and dynamic material characterization
- ✓ validation of material cards on up to seven different load cases
- ✓ calibration of complex failure models (e.g. DIEM, GISSMO)
- ✓ detailed report to depict performance of material card



isoP

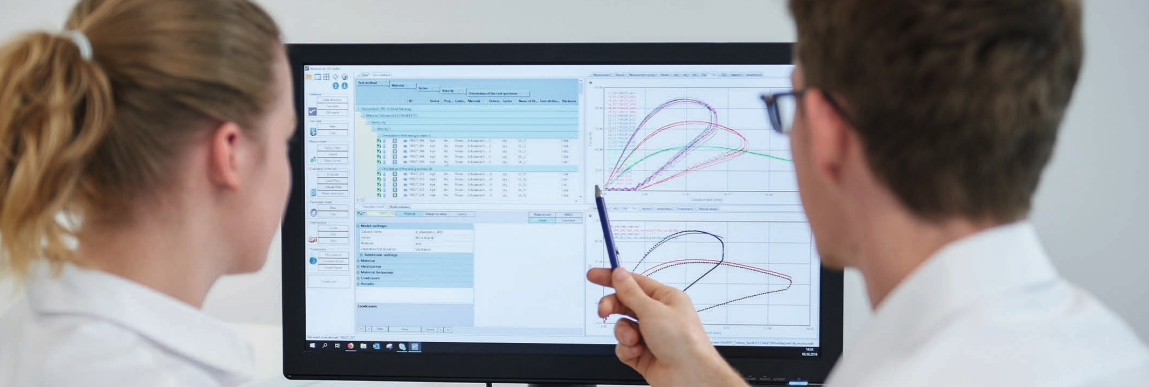
frP

comP

foam

join

metP



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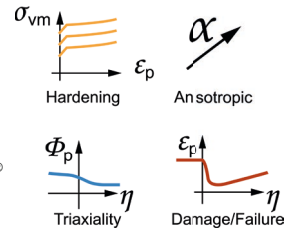


VALIMAT

from test to material card

What is it good for?

- ✓ stand-alone software or in combination with IMPETUS® or LINOVIS®
- ✓ test- and model database system for efficient organization
- ✓ import of external measurement data



Fully parameterized material models for a variety of use-cases

- ✓ LS-Dyna®, Pam-Crash®, Abaqus® support
- ✓ efficient and fully customizable work-flow with template databases
- ✓ integrated material models or custom option via XML-scheme
- ✓ automated FE-model build-up for different load cases

One click solution from deformation to failure

- ✓ fully automated AutoFit optimization process for material card generation
- ✓ customizable AutoReport creation with many plotting options



I N P H Y S I C S W E T R U S T



BATTERY

testing & simulation

Test Capabilities

- ✓ from standardized procedures to customized set-ups
- ✓ all common abuse scenarios - electrical, thermal, mechanical
- ✓ all cell types, from single cells to cell modules
- ✓ durability tests of battery pack materials and components

Simulation Services

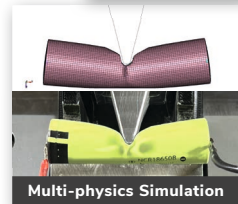
- ✓ automated model generation for multi-physics simulations
- ✓ identification of mechanical, thermal and electric properties
- ✓ „Digital Twins“ of battery cells

Your Benefit

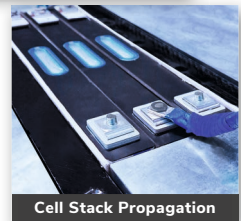
- ✓ controlled, safe and professional testing conditions
- ✓ consideration of customer-specific test set-ups and requirements
- ✓ realistic prediction of cell behavior by validated simulation models
- ✓ support of your safety and performance relevant battery development



Abuse & Material Testing



Multi-physics Simulation



Cell Stack Propagation



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