

Material testing and characterization facilities

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Tampere Microscopy Center at Tampere University

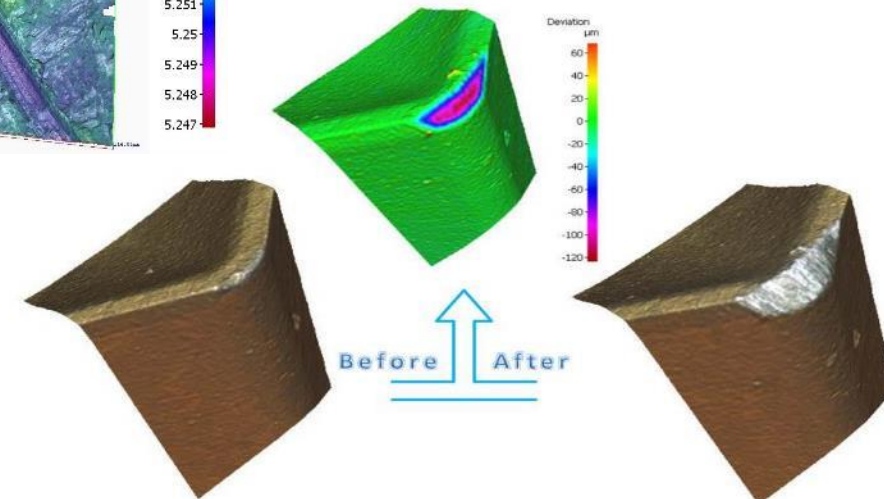
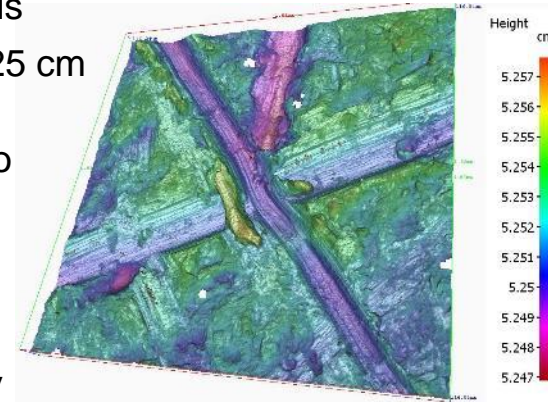
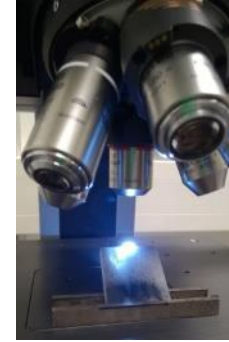
- Scanning electron microscopy
- In-situ SEM nanoindenter

Alicona InfiniteFocus G5 for surface profile 3D measuring

InfiniteFocus is a highly accurate and fast optical 3D measurement system. The range of measurable surfaces is almost unlimited, enabled by the use of coaxial lighting and an optimized LED ring light.

Key analysis features are:

- Large area imaging with automatic stitching
 - Real optical 2D image, and 3D analysis with perfect depth focus
 - Maximum sample weight is up to 30 kg and size can be up to 25 cm in height and 30 cm in lateral directions.
 - High optical resolution: vertically up to 10 nm and laterally up to 0.44 μm with high imaging speed
- Surface roughness measurements
 - Profile roughness and surface texture (area based roughness)
- Combining texture (optical microscope) and topography (profilometer) data in single measurement result
- Measurements of real 3D objects with 360° rotation
 - Difference measurements, e.g., before and after use measurements of components
 - Possibility to import from and export to CAD/FEM software



Optical microscopes

Materials microscope system Leica DM 2500

- Incident and transmitted light
- Bright field and dark field reflectors
- Polarizator R/P, L29x11.5
- Analyzer 180°
- Objectives: 5x, 10x, 20x, 50x and 100x
- 3.3 Mpix Leica DFC320 R2 digital camera (resolution 2088 x 1550 pixels)
- Leica Application Suite-program



Zoom stereo microscope Leica MZ 7.5

- 2x objective, magnification range 12,6x - 100x
- 0,5 objective, magnification range 3,2x - 25x
- Leica CLS 150 XE cold light source 21V 150W
- Segment ring light with 6 segments, Ø 7,6mm
- 5 Mpix Leica DFC420 digital camera (resolution 2592 x 1944 pixels)
- Leica Application Suite-program with Multifocus module



Optical microscopes

Optical microscope Leitz Laborlux

- Objectives 2.5x, 10x, 20x, 40x, 100x (oil immersion)
- Leica DFC290HD digital camera
- Leica Application Suite V3 -program

Stereomicroscope Stemi SV8

- Field of vision with Polaroid DMC camera:
1,125 mm x 1,5 mm, 9 mm x 12 mm

Microm HM 325 microtome & Zeiss Axioskop 40 optical microscope

- Suitable system for thin section studies of polymer films or coatings

Heating and freezing stage Linkam LTS120 – Peltier system

- Temperature range -40°C - 120°C
- Sample area 40x40 mm
- Gas tight chamber
- Temperature stability and accuracy to 0.1°C
- Maximum heating / cooling rate of 30°C/min
- Response time of <1 second at 5°C/min at 50°C
- LWD objectives: 2.5x, 10x, 20x

Specimen preparation

Versatile laboratory for specimen preparation

- Automatic grinding and polishing Equipments: Struers Tegamin-30 and Buehler Phoenix 4000
- Manual grinding machines: Buehler MetaServ 250 and Struers LaboSystem
- Glassgrinding machine: Kristall 2000S
- Electrolytic polishing and etching machine: Struers LectroPol -5
- Hotmounting Equipment: Struers CitoPress-10
- Goldmounting Equipment: Struers CitoVac
- Precision cutting machines: Accutom 50 and 100
- Cut-off machines: Discotom 5 and 10
- Manual cut-off machine: Buehler Isomet
- Density meter: Wallace
- Vibratory Sieve Shaker: Fritsch



Tampere Microscopy Center

Tampere Microscopy Center provides instruments, training and services for researchers in Tampere University, in other research institutes and in industry

- Transmission electron microscope (Jeol F200 S/TEM)
- Analytical high resolution scanning electron microscope (Zeiss UltraPlus FE-SEM)
- Focused ion beam microscope, FIB-SEM (Zeiss Crossbeam 540)
- Other scanning electron microscopes
 - Zeiss Ultra55 FE-SEM with Raith e-beam lithography
 - Jeol JSM-IT500 variable pressure SEM with EDS
 - LEO 1450 SEM with Alemnis In-situ Nanoindenter
 - Tescan Vega SEM with EDS
- Raman microscope (Renishaw InVia Qontor)
- Comprehensive sample preparation equipment for EM studies

More information: research.tuni.fi/microscopy/

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Tampere Microscopy Center

JEOL JSM-IT500

JEOL JSM-IT500 is a variable pressure tungsten filament scanning electron microscope (SEM) with EDS. Provides information on surface topography and elemental composition.

- Resolution (30 kV): 3.0 nm (high vacuum), 4.0 nm (low vacuum)
- Low vacuum mode up to 650 Pa
- High and low vacuum secondary and backscattered electron detectors
- Seamless transition from optical to SEM image
- 3D imaging
- Real time EDS analysis with 30 mm² dry silicon drift detector



Tampere Microscopy Center

Zeiss LEO 1450 SEM

Zeiss LEO 1450 is a tungsten filament SEM with large chamber that is dedicated for in-situ testing.

- Resolution (30 kV): 3.5 nm
- Magnification range: 9x to 900,000x
- Secondary and backscattered electron detectors
- 5 axis motorized stage (XYZRT)

An Alemnis in-situ nanoindenter is installed inside the SEM chamber for in-situ micromechanical testing.



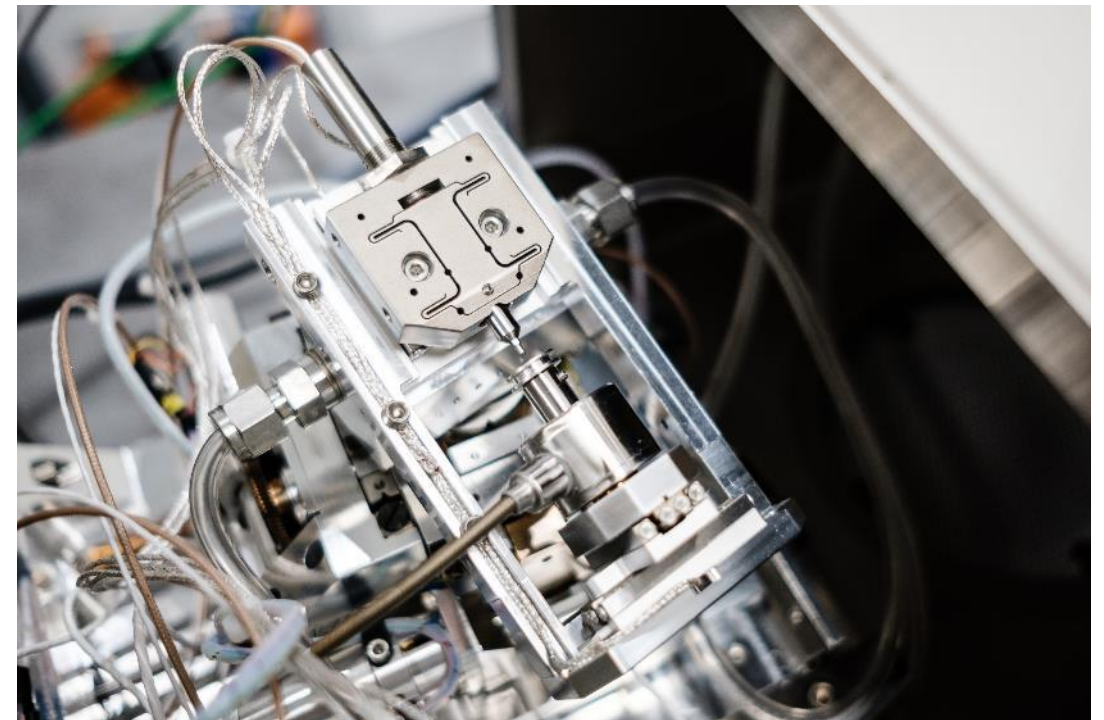
Tampere Microscopy Center

Alemnis in-situ SEM nanoindenter

Alemnis in-situ nanoindenter can perform indentation, micropillar compression, microcantilever fracture and other micromechanical tests inside a SEM over a wide range of temperatures and strain rates. All classes of materials (metals, ceramics, plastics, composites, glasses, etc.) can be tested at small length scales.

Specifications:

Load range	4 μN – 2 N
Displacement range	40 μm
Strain rate range	10^{-5} - 10^4 s^{-1}
Frequency range	Up to 10 kHz
Temperature range	-150 - 1000 $^{\circ}\text{C}$
Loading type	Compression and tension
Indentation tips	Berkovich, cube corner, spherical, flat punch, conical, tensile grippers
Control modes	Load & displacement controlled



Part of Tampere Microscopy Center <https://research.tuni.fi/microscopy/instruments/>
Further details and examples on the IMPACT group website <https://research.tuni.fi/impact/>

Structural and surface analysis

X-Ray Diffractometer (XRD)

FT-IR spectroscopy

Drop shape analyser

Gas adsorption analyser

Panalytical Empyrean Multipurpose Diffractometer (XRD)

X-ray diffraction (XRD) is an analytical technique primarily used for phase identification of a crystalline material. It also provides information on unit cell dimensions. Typically, the analyzed material is finely ground, homogenized, and average bulk composition is determined, but also bulk materials can be analyzed.

- Anode materials: Cu, Co
- Qualitative and Quantitative Phase Analysis
- Rietveld Analysis
- Residual Stress Measurement
- Texture Analysis
- Small Angle X-ray Scattering
- Grazing Incidence X-ray Diffraction Analysis of thin film material



Fourier-Transform Infrared (FT-IR) spectroscopy, Bruker Optics Tensor 27

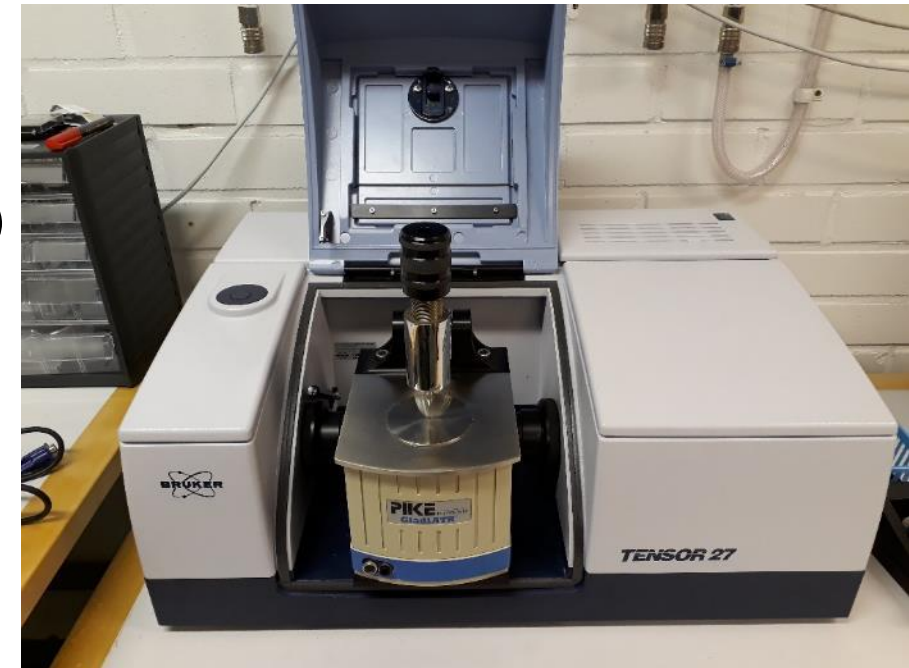
Infrared spectroscopy is based on the absorption of IR radiation by chemical bonds. The collected raw data is converted into spectrum via Fourier transformation. FT-IR spectroscopy can be used to identify unknown materials and determine the quality or consistency of a sample. Available accessories enable measurement of solids, liquids (ATR), powders (Integrating sphere/DRIFTS) and the output gasses of TGA measurements (TGA-FTIR).

Technical details:

- Radiation source: MIR
- Spectral Range: 4000 to 400 cm^{-1} (depending on the detector)
- Detectors: MCT and DLATGS

Measurement methods

- ATR with diamond or germanium crystal
- Reflection-absorption (RA-IR), angle 30-80°
- Integrating sphere
- TGA-FTIR

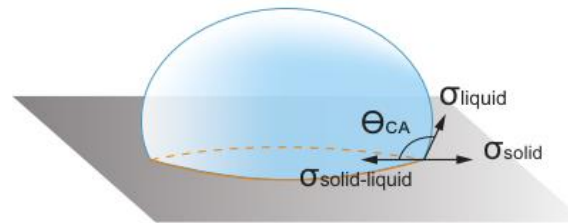


Krüss DSA100 Drop Shape Analyzer

Wettability and wetting of the surfaces can be analysed with drop shape analyzer placed in controlled room (temperature 21°C and relative humidity 50%). Many solid materials and liquids can be tested. Small sample size and liquid amounts used (a few cm/ μ L).

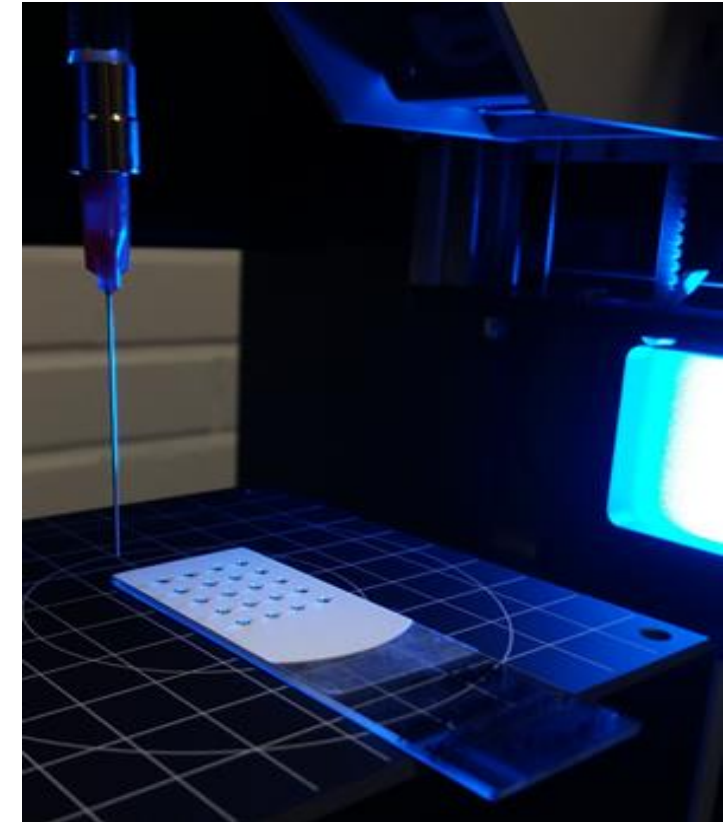
Measured values based on image analysis of droplets:

- Static contact angle
- Advancing and receding angles
- Hysteresis
- Sliding angle/roll-off angle
- Surface free energy
- Surface tension



Droplet behavior with Peltier temperature control plate

- Temperature range -20 - +120°C
- Heating and cooling rate +/- 1K/s
- Maximum sample size (L x W x H) 90 x 90 x 20 mm



Micropore Gas Adsorption Analyzer

Micromeritics 3Flex 3500

3Flex gas adsorption analyzer can be used to analyze surface area and pore size of the powder or fibrous samples by adsorption and desorption of the gases. Equipment is capable of measuring 3 samples simultaneously with different gases if needed, while pretreating 6 samples. As a result of the measurement is full adsorption-desorption isotherm, from where for example specific surface area, pore volume and pore size distribution can be determined in range of 0,35 to 500 nm

Technical information of the device

- 3 measurement ports, from which 2 are equipped to micro pore range (below 2nm)
- 2 sizes of sample tubes, inner diameter of the tube 6 mm and 9mm
- For powder and fibrous samples, which can be fitted inside the sample tube
- Analysis range $1,3 \cdot 10^{-8}$ - 1.0 P/P₀
- Minimum measurable surface area 0,01 m²/g
- Analysis gases: nitrogen as standard, also other gases can be used



Mechanical Testing

Hardness testing

Mechanical testing machines

Impact pendulums

Hopkinson split bar (HSB)

High velocity particle impactor

Drop-weight impact tower

Resonant ultrasound spectroscopy (RUS)

Linear Density and Tensile Tester for Single Fibres

Hardness testing

Duramin-A300 hardness testing system

- Vickers: HV 0.1 - HV 30; standard DIN EN ISO 6507
- Brinell: HB1/2.5 - HB2.5/31.25; standard DIN EN ISO 6506
- Knoop: HK 0.1 - HK 1; standard ISO 4545
- Max. sample: height 150 mm, weight 20 kg.



Matsuzawa MMT-X7 micro Vickers hardness tester

- Testing force: 49,03 - 9807 mN (HV0,005 – HV1).
- Max sample: height 120 mm, depth 160 mm.



Shore A and Shore D hardness tester

- The Shore A Hardness Scale measures the hardness of flexible rubbers. Semi-rigid plastics can also be measured on the high end of the Shore A Scale.
- Shore D Hardness Scale measures the hardness of hard rubbers, semi-rigid plastics and hard plastics.

Materials testing machines

Several uniaxial materials testing machines for different testing purposes

- **Instron 8801 – 50kN and 100kN servohydraulic machines**
 - Tensile, compressive, bending and fatigue tests
- **MTS 810 Test Star – 100kN servohydraulic machine**
 - Tensile, compression, bending and fatigue tests
- **Instron 5967 – 30kN table top universal testing machine**
 - Tensile, compression, bending tests
- **Instron 1185 / retrofit 5500 – 100kN universal testing machine**
 - Tensile, compression, bending tests
- **Testometric M500 – 25kN table top universal testing machine**
 - Main usage in testing of fibers, yarns and fabrics
- Possibility to use the high resolution stereomicroscope-based Digital Image Correlation (DIC) systems to measure specimen deformation in all of the above setups.

Servohydraulic materials testing machine Instron 8800

A servohydraulic uniaxial materials testing machine used for the determination of quasi-static, fatigue (up to 20 Hz) and low rate dynamic material properties (strain rate below ~ 100 %/s).

The equipment consists of two separate machines, which have slightly different characteristics:

Machine 1: Maximum loading ± 100 kN, maximum actuator movement 150 mm

Machine 2: Maximum loading ± 50 kN, maximum actuator movement 250 mm

- Typically used actuator rate between 0.001 mm/s ... 50 mm/s.
- Testing in tension and compression as well as in 3- and 4-point bending and shear (with suitable specimen geometry).
- Small and large hydraulic wedge grips and a large variety of custom made fixtures for specimen gripping/loading.
- Temperature control: heating/cooling chambers (achievable temperature range ~ -150 °C ... $+350$ °C) and induction heater (several hundreds of degrees depending on the test material).
- Maximum data sampling rate 5 kHz, possibility for real-time analog output to an external recording device, digital input/output for triggering external devices.



100kN Instron 8801 materials testing machine, large hydraulic wedge grips, heating chamber at the background

Servohydraulic materials testing machine Instron 8800

- Dynamic (fatigue testing-rated) load cells, size and calibrations:
 - 100 kN (class 1)
 - 50 kN (class 1)
 - 5 kN (class 0.5)
 - 1 kN (class 0.5)
 - 250 N
- Extensometers:
 - Gauge length 50 mm, travel -5...+ 50 mm, for static loading only, (class 1)
 - Gauge length 6/12,5/25 or 50 mm, travel +/- 5 mm, suitable for dynamic and fatigue loading (class 0.5)
 - Transverse averaging extensometer for the measurement of transverse strain in the tensile test of a sheet material, for static loading only
 - Transversal extensometer is mainly used to determine r-value of sheet materials. An alternative possibility is to use DIC.

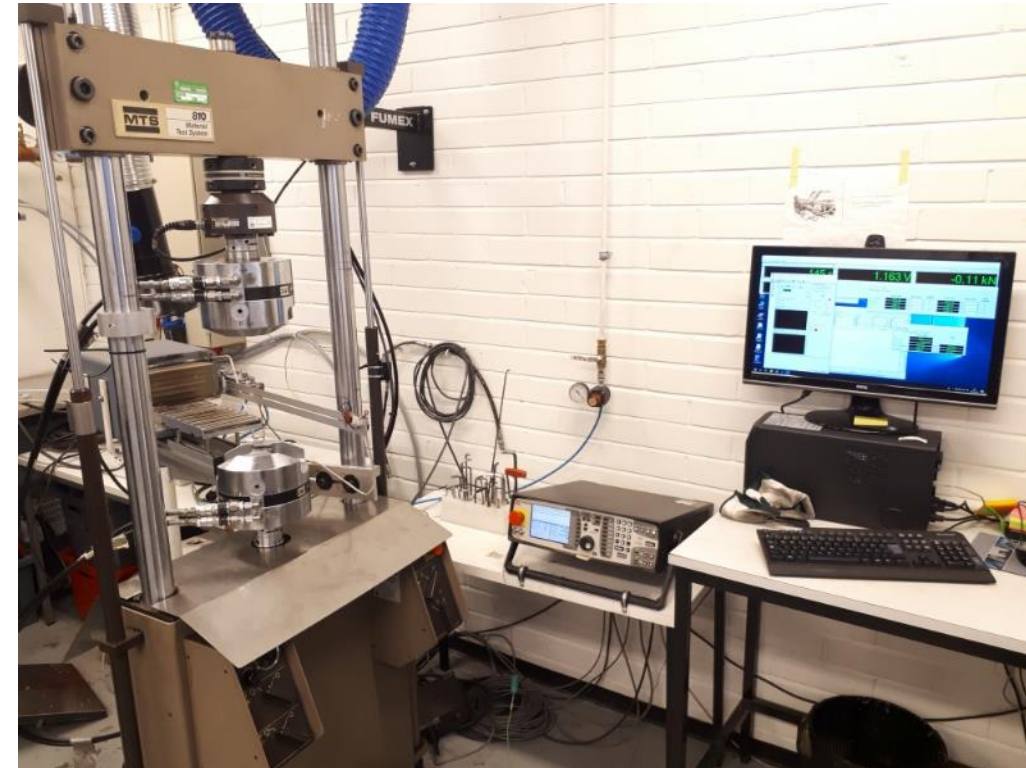


50kN Instron 8801 with DIC equipment.
Environmental chamber at the background.

Servohydraulic materials testing machine MTS 810 Test Star

A servohydraulic uniaxial materials testing machine used for the determination of quasi-static, fatigue (up to 20 Hz), and low rate dynamic material properties (strain rate below ~100 %/s).

- Very similar in performance to Instron 8800 machines
 - Actuator rate 0.001 mm/s - 50 mm/s.
 - Tensile, compression, 3- and 4-point bending, shear and fatigue testing.
 - Small and large hydraulic wedge grips, large variety of custom made fixtures.
- Induction heaters and ovens, temperatures up to over 1000 °C.
- Maximum data sampling rate 1024 Hz, possibility for real-time analog output to an external recording device, digital input/output for triggering external devices.
- Dynamic (fatigue testing-rated) load cells, size and calibration:
 - 100 kN (class 0.5)
 - 10 kN (class 2)
- Extensometers and calibrations:
 - Model 632.50F-4: gauge length 12 mm, operating range +2,4/-1,20 m, strain range +20%/7-10%, temperature limit +1200°C (class 1)
 - Model 632.11C-20: gauge length 25 mm, travel $\pm 3,75$ mm, temperature range -100°C/+150°C, for static loading only (class 0.5)
 - Model 632.06F-20: travel +21,16/- 21.17 mm



100kN MTS 810 Test Star with oven used for press hardening experiments

Other mechanical testing machines

Instron 5967

A mechanical tensile testing machine.

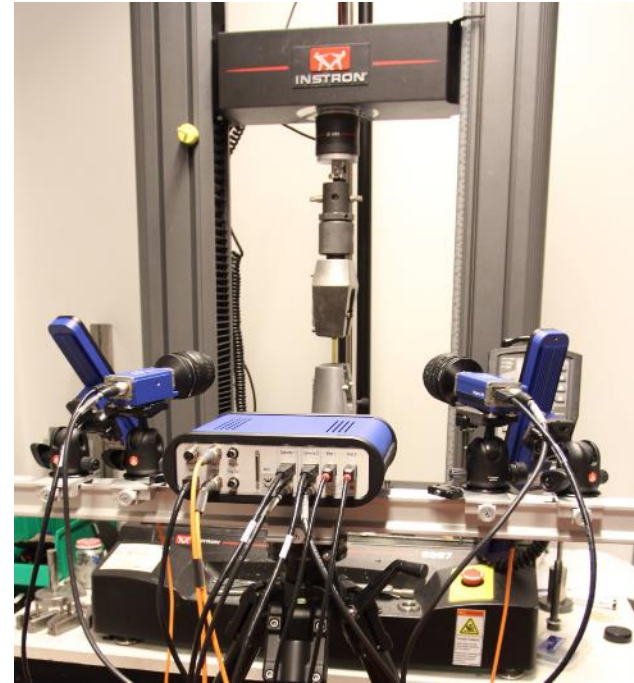
- Load cells:
 - 5 N, 0.5 kN, 2 kN (class 0.5), 30 kN (class 0.5)
- Extensometers:
 - Gauge length 50 mm, travel $\pm 2,5$ mm
 - Gauge length 10, 20, 25, 50, 100 or 200 mm, travel 750mm
- Total movement 1140 mm

Instron 1185 / retrofit 5500

- A mechanical tensile machine equipped with 100kN load cell.
- Testing in tension and compression as well as in 3- and 4-point bending.
- Possibility to use 6...50mm gauge length static/dynamic extensometers.

Mechanical tensile testing machine for fibers, yarns and fabrics (Testometric M500)

- Load cells: 20, 100, 250, 2500 N and 25 kN



Instron 5957 table-top materials testing machine with the high resolution stereomicroscope-based DIC equipment



Impact pendulums

Instrumented equipment Ceast Resil 5.5 (Max 5 J)

- Instrumented impact pendulum system with data acquisition and analysis for standard Charpy and Izod impact tests.
 - Records load-time curve of the impact
- 0.5 J, 1 J, 2 J (instrumented), 4 J (instrumented) hammers

Non-instrumented Zwick impact pendulum (Max 50 J)

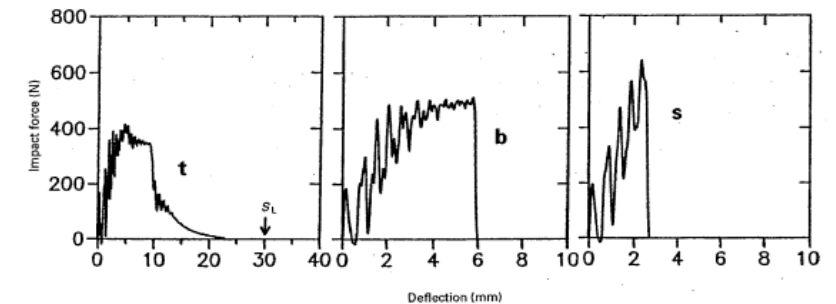
- Non-instrumented impact pendulum for standard Charpy and Izod impact tests. Charpy hammer is 50 J and Izod hammer 25 J.
- Tensile impact testing with 25 J hammer

Non-instrumented Frank impact pendulum (Max 4 J)

- Charpy and Izod
- Tensile impact testing with 2 J hammer

Non-instrumented WPMA impact pendulum (Max 300 J)

- Charpy



The polymer processing facilities together with a cutting-in equipment for the notches enable fabricating polymeric impact test specimens directly from the raw materials.

Split Hopkinson Pressure Bar

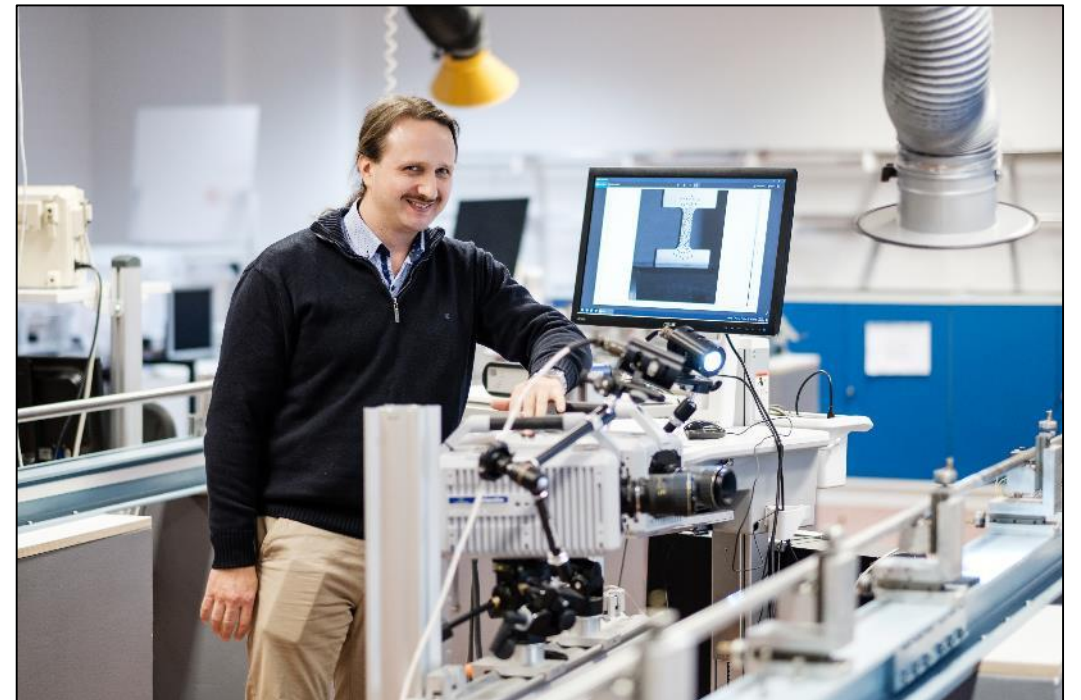
Split Hopkinson Pressure bar or Kolsky bar technique is used to measure the stress-strain response of materials at high strain rates, typically in the range 10^2 - 10^4 s⁻¹. The SHPB method is based on the propagation of longitudinal stress waves in elastic bars. The SHPB method is a highly specialized research tool, the designing, building, and utilization of which requires versatile understanding of the propagation of elastic waves in solids, modern machine design, and instrumentation of electronic measurement devices and data acquisition systems. At TAU, there are three SHPB devices, two for compression and one for tensile testing.

Capabilities:

Specifications

Type of loading:	Compression, tension, or shear.
Duration of the loading pulse [μ s]:	50 – 600
Strain rate range [s^{-1}]:	$2 \cdot 10^2 - 10^4$
Loading range [kN]:	0 – 250
Temperature range [$^{\circ}$ C]:	-190 – 1000

More details and examples on the IMPACT –group website
<https://research.tuni.fi/impact/>

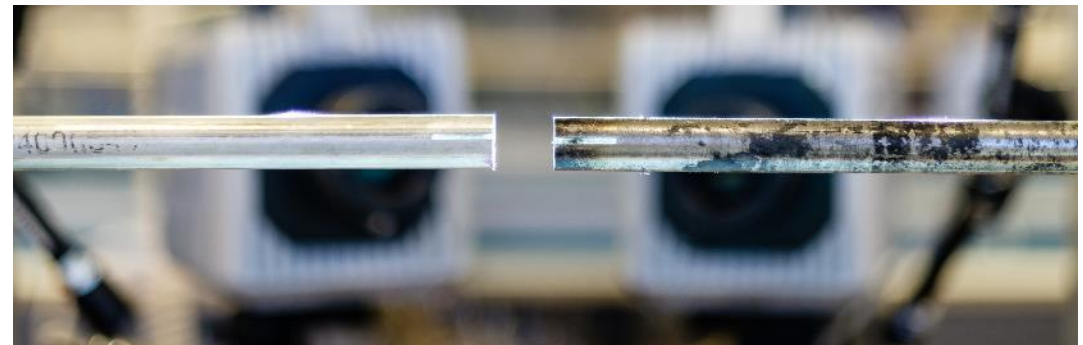
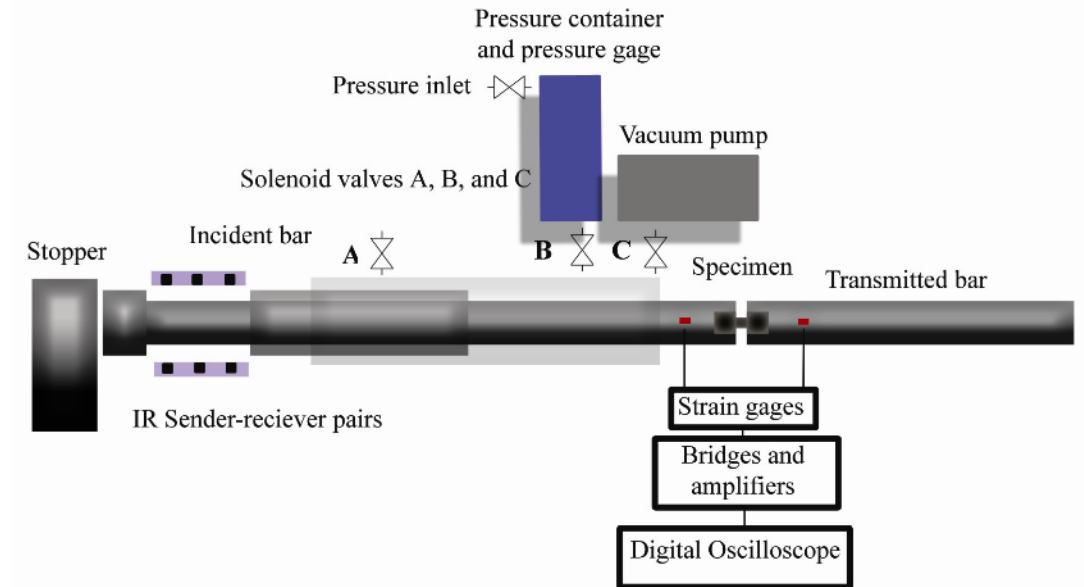


Tension Split Hopkinson Pressure Bar

This equipment allows mechanical testing of dog bone tensile samples at strain rates ranging from 500 to 2500 s⁻¹.

Key Features:

- The tensile apparatus uses 4340 steel incident bars and 2007 aluminum alloy transmitted bars.
- The diameter of the bar is either 22 or 12 mm, and the length from 3000 mm to 6000 mm.
- The length of the striker varies from 500 to 1600 mm.
- The signals from the strain gages are amplified using Kyowa CDV 700A series signal conditioners and recorded using a 12-bit 10 MHz Yokogawa digital oscilloscope.
- The tensile HSB device is also equipped with a high temperature system, which allows experiments as high as 1500°C.



High Velocity Particle Impactor

Developed for experimental research of high speed impacts of small particles. This device simply accelerates small balls or cylinders to high velocities and impacts them to the sample target at a preset angle. The device was originally developed for model verification purposes, but has been also used to carry out various impact tests including High Temperature Taylor Experiments.

Key Features:

- Variable impact angle and energies
- Projectile speeds: 30-200m/s
- Suitable for metals, coatings, composites, elastomers, hybrids...
- Projectiles: Metallic or ceramic bearing balls, cylinders, bullets, and rocks.
- Provides good opportunity to record the impact with high speed video cameras and 3D displacement and full field strains with Digital Image Correlation Systems.
- Low temperatures down to -80 °C has been tested. High Temperature Taylor tests carried out at 700°C



Drop-weight impact tower

Rosand Instrumented Falling Weight Impact Tester, Type 5

Test parameters

- Max drop height $h = 3 \text{ m}$
- Impactor mass $m = 2.7 - 25 \text{ kg}$
- Impact energy $E = 2.5 - 735 \text{ J}$

Instrumentation

- Contact force of the impactor (max 60 kN)
- Displacement of the impactor
- Impact velocity

Other

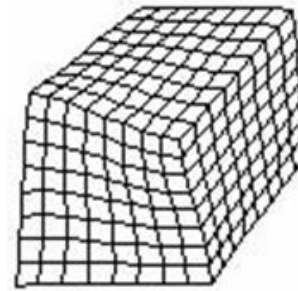
- Several impactor head shapes and sizes available (also custom heads possible)
- Several specimen fixtures available (also custom fixtures possible)



Resonant ultrasound spectroscopy (RUS)

Resonant ultrasound spectroscopy (RUS) measures the vibrational response of test samples when subjected to mechanical stimulation

- In practice for dynamic Young's modulus determination
- For a piece of solid material, the natural mechanical vibrational frequencies are determined by the material's mass, geometric parameters, and elastic constants
- Mass and geometric factors can be measured as well as (using RUS) the natural vibrational frequencies => elastic constants can be back calculated



Single fibre linear density and tensile tester, FAVIGARPH

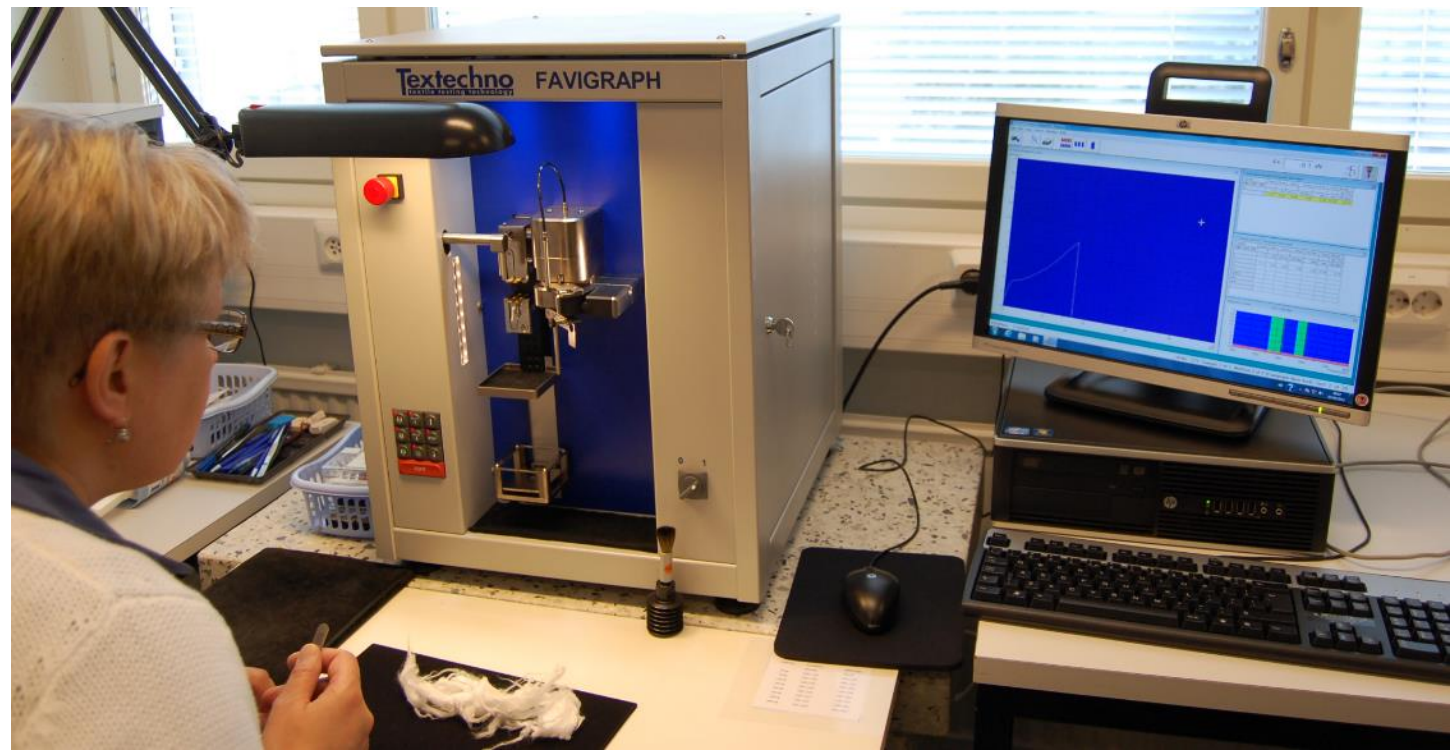
SFS-EN ISO 1973 Textile fibres - Determination of linear density - Gravimetric method and vibroscope method

SFS-EN ISO 5079 Textile fibres - Determination of breaking force and elongation at break of individual fibres

- linear-density measuring head and tensile test section
- automated a transfer clamp between the two measuring systems
- load cells 20 cN and 100 cN
- pre-tension weights 50 mg - 7g
- draw-off clamp speed 0.1 - 100 mm/min,
return speed 300 mm/min,
max. travel of draw-off clamp 100 mm

Also available:

- Yarn number measurement devices
- Yarn twist meter
- Yarn evenness tester



High Speed Optical and IR Imaging and Digital Image Correlation

TELOPS Fast IR-1500 M2K High Speed IR Camera

Fluke IR Ti400 Camera

Digital image correlation systems (DIC)

- DAVIS10
- Low Speed System
- High Speed System

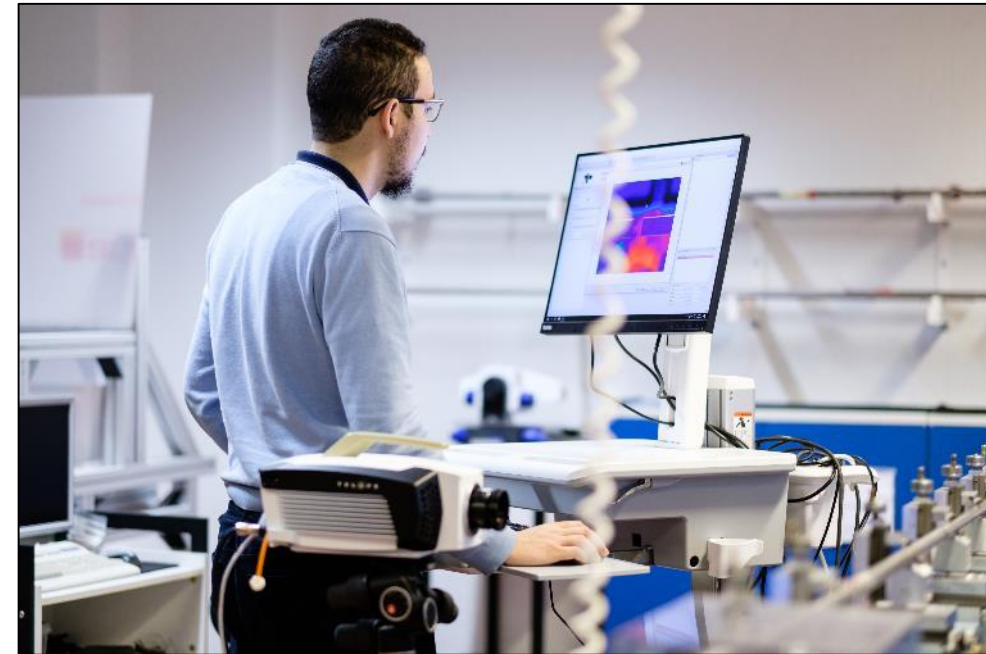
High speed video systems

- Cordin 535-16
- Memrecam fx K5

High speed IR Camera

The TELOPS Fast IR-1500 M2K high speed IR camera offers high-speed thermal imaging with high temporal resolution. Therefore, it is ideal to analyse dynamic events.

- Full size image of 320×256 pixels up to 2000 frames per second. At higher speeds, the size of the image decreases.
- Maximum frame rate of 90 kHz with an image of 64×4 pixels.
- 4-position filter wheel that allows imaging at a broad range of temperatures up to 1500 °C.
- Several optical configurations available to cover various field of views and working distances
- Spectral range of 1.5 to 5.5 μm
- Can be used simultaneously with optical cameras and Digital Image Correlation



More Details and examples on
the IMPACT –group website
research.tuni.fi/impact/

IR camera Fluke Ti400

Fluke Ti400 is a hand-held longwave thermal camera, with eg. autofocus and wireless remote control. The camera is equipped with versatile tools which, e.g., find the maximum temperature from the image or the temperature of certain points. Voice and text annotations can be embedded into the pictures, which can be exported in many file formats. The camera has also a video output of the thermal images (30Hz) as .avi and also includes normal visible light camera (5 Mpix).

- Spectral range: 7.5 to 14 μm
- Temperature range: -20°C to $+1200^{\circ}\text{C}$
- Operating temperature range: -10°C to $+50^{\circ}\text{C}$
- Thermal sensitivity: 0.05°C at 30°C
- Accuracy (depends on the used range): $\pm 2^{\circ}\text{C}$ or $\pm 2\%$
- Resolution: 320x240
- Weight with battery: 2.4 kg
- Image capture frequency in the screen: 60 Hz refresh rate
- Field of view/min focus distance: $24^{\circ} \times 17^{\circ}/0.15\text{ m}$



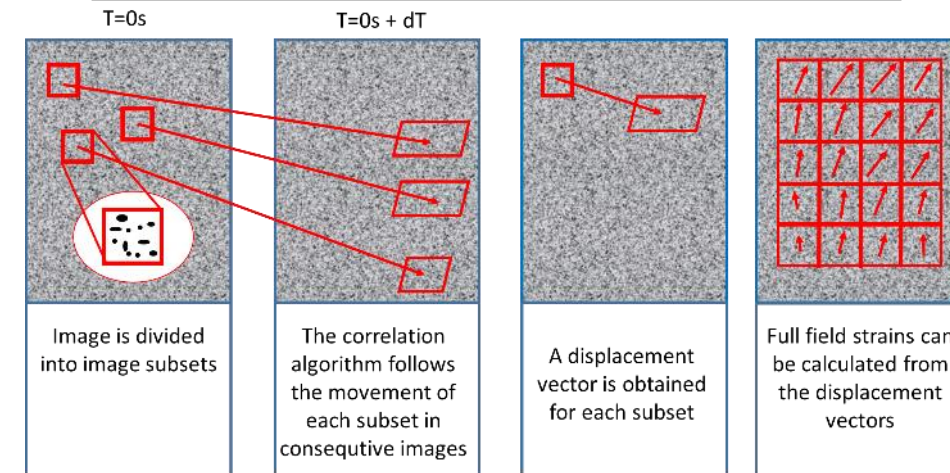
Digital Image Correlation (DIC)

Digital Image Correlation is an optical photography based method to calculate full field displacement fields from a moving or deforming object.

The benefits are:

- Non contact, non intrusive
- Full field data (thousands of mini extensometers) and extraction of e.g. strain plots along a 1D line
- System is not damaged when sample fails
- Suitable in harsh environments (chambers)
- Possible to use where specimen is submerged in solution
- Identify strain hot spots over a larger area
- Visualization of results and easy comparison with FEM simulations
- Do not need to know where to place the gauge / extensometer before the test

We are currently using DAVIS10 system from LaVision (www.lavision.de) with latest updates.



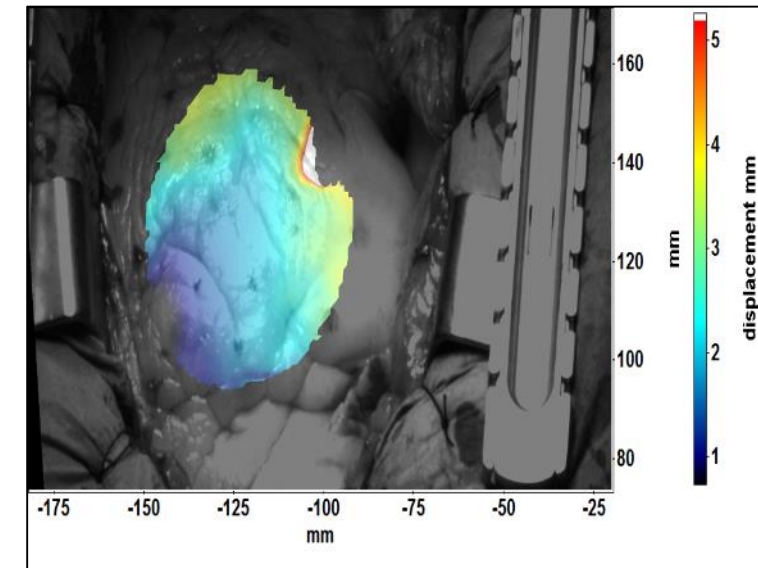
Digital Image Correlation (DIC)

Low rate system

- 2 cameras: Imager E-Lite 5MPix CCD cameras.
- 12bit images, 12 fps at full resolution
- Lightweight mounting system for easy access of cameras and lights
- Pulsed LED Lights. Operated directly from Davis software
- Additional Zeiss Discovery v.8 stereo microscope with horizontal mounting system



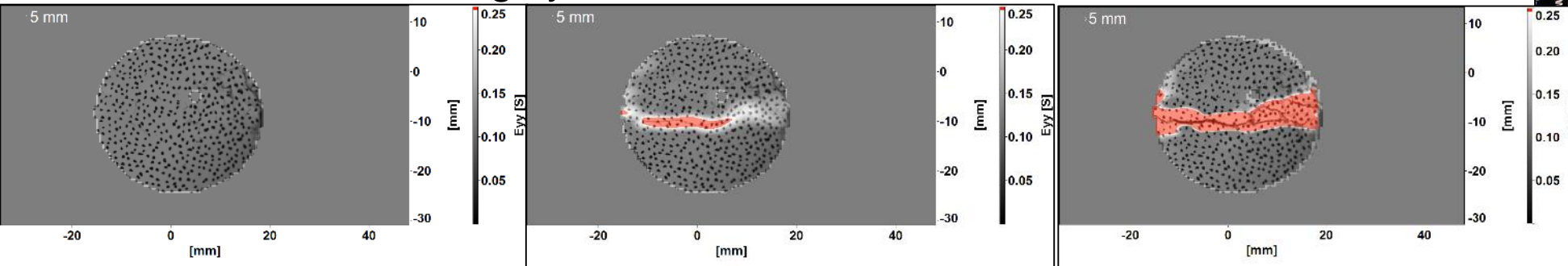
More Details and examples on
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Digital Image Correlation (DIC)

High rate system

- 2 Cameras: Photron SA-X2
- 12 bit images, 1MPix maximum resolution. 12.500 fps at max.res. Higher fps at reduced resolution, e.g. 200kHz @ 256*152
- 16GB of internal memory, recording time around 0.7 to 10 seconds depending on the resolution and fps
- A rigid mounting system for the cameras and lights
- High speed trigger unit
- DecoCool high power lights
- Additional Zeiss Discovery v.8 stereo microscope with horizontal mounting system



High Speed Video Systems

Cordin 535-16

Cordin model 535-16 is a High Resolution Rotating Mirror CCD Framing Camera System. This system use a complex optical system centered on a multi-faceted mirror that spins at very high speeds. This action distributes the image to individual CCD channels which record the frames. This approach yields the best image quality available in ultra-high speed applications.

- Number of Frames: 16
- Maximum framing Rate: 1 million
- Minimum Interframe time: 1.0 us
- Minimum Exposure Time: 800 ns
- Front Optics: Single objective lens system (no parallax)
- Objective Lens: Nikon F-mount
- Resolution: 1000 x 1000 pixels
- Pixel size: 7.4 x 7.4 mm
- Dynamic Range: 10 bit
- Device Type Full resolution progressive scan

High Speed Video Systems

Memrecam fx K5

Memrecam fx K5 provides ultra high light sensitivity, ultra high speed and mega pixel resolution. It is a fully self-contained, digital, high-speed video system that records brilliant colour images or crisp monochrome images. The robust Memrecam fx K5 is perfect for any high-speed imaging application being performed in a hazardous environment. The Memrecam fx digital cameras allow the user to record mega pixel images for more than 10 seconds at 1000 fps and over one minute at reduced resolution.

- Megapixel Sensor
- Frame rates up to 168,000fps
- Ultra-High Light Sensitivity— ISO 5,000 Colour & 32,000 Monochrome
- 1280 x 1024 resolution
- Gigabit Ethernet control 100m+ or 100baseT Ethernet operation.

Non-destructive testing methods

Barkhausen noise method

Ultrasound / phased array ultrasound

Residual stress measurement

Barkhausen noise method

Barkhausen noise measuring device Rollscan 350 can be used for non-destructive testing of ferromagnetic components. The measurement is based on the magnetic properties of the ferromagnetic materials. The method is suitable for characterization of surface properties. The device can be used for evaluation of surface residual stresses and changes in the surface hardness/microstructure. The Barkhausen noise method can be used i.e. in final inspection of ground gears for detecting grinding burns and to inspect surface changes due to heat treatments.

- Rollscan 350 Barkhausen noise signal analyzer
- Barkhausen noise sensors for different surface geometries
- ViewScan and MicroScan software for data acquisition and analysis



Ultrasound / phased array ultrasound

Ultrasound inspection is used for internal flaw detection. Portable ultrasound flaw detector Phasor XS provides the use of the conventional pulse-echo method and the advanced phased array inspection with special phased array probe. The phased array provides simultaneous inspection with multiple beams from a single location.

Phasor XS

- Portable battery-powered ultrasound flaw detector
- JPEG image reporting and data storing to SD card

Phased array mode:

- 16 elements combined in one phased array probe
- Full color, real-time sector image display

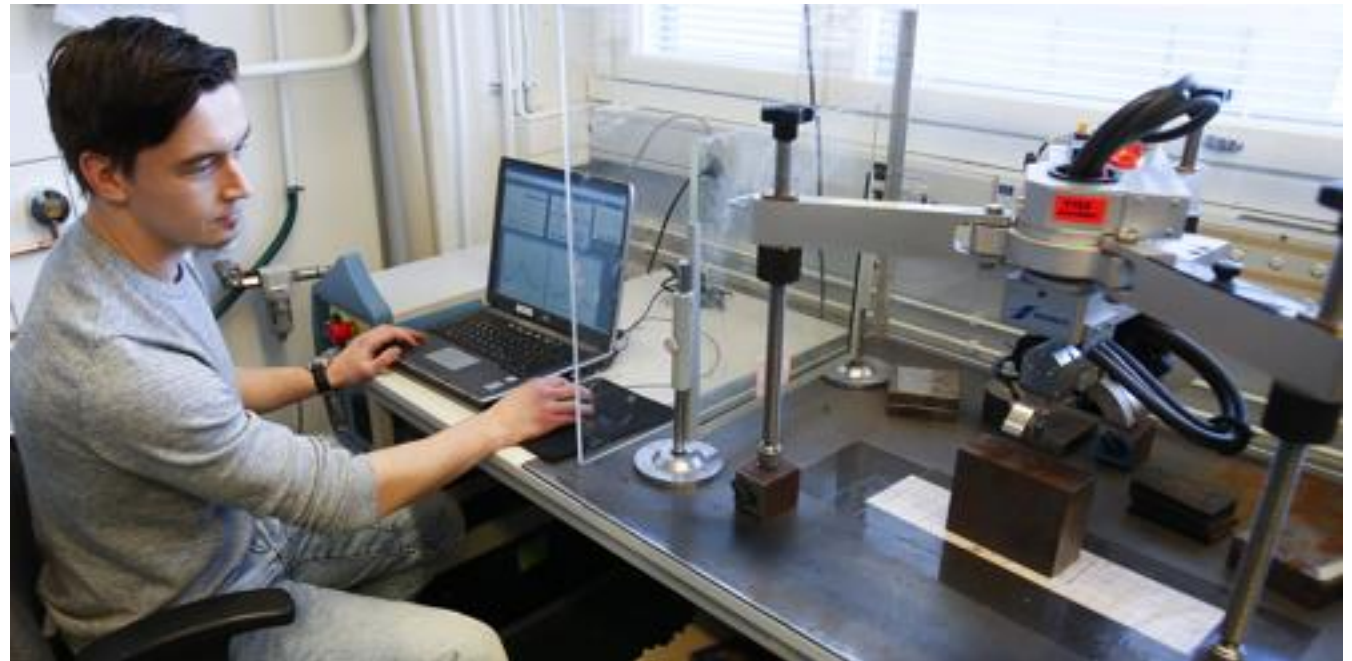


Residual stress measurement device

Xstress 3000 G2

Small and portable X-ray diffraction based stress analyzer. Suitable also for retained austenite measurements. Measurement depth varies from 1-50 μm from the surface according to the used X-ray tube.

- Residual stress measurements
- Retained austenite measurements
 - Four peak retained austenite testing
- X-ray tube (anode): Cr
- Adjustable 2Θ -angle from $+100^\circ$ to 165°
- Replaceable collimator with different spot sizes
- Utilises XTronic software for calculating the residual stress or retained austenite values.



Thermal analysis

Differential Scanning Calorimetry (DSC)

Dynamical Mechanical Analysis (DMA)

Thermogravimetric analyser (TGA)

Simultaneous Thermal Analyser (STA)

Laser flash analysis

Dilatometer

Cone calorimetry

HDT/Vicat

Differential Scanning Calorimetry (DSC)

Netzsch DSC 214 Polyma

DSC can be used to determine transition temperatures and enthalpy changes in solids and liquids under controlled temperature change. Typical research subjects are characteristic temperatures of the material (e.g. melting, crystallization, glass transition temperatures) and their enthalpies, amorphous and crystalline behaviour of materials, curing behaviour and the degree of cure, specific heat, compatibility between material components, effects of different additives. Measurements of OIT (oxidation induction time) are possible. Temperature-modulated (TM-DSC) measurements allow separating some overlapping effects (reversing from non-reversing).

Technical details:

- Liquid nitrogen cooling
- Automatic sample changer (ASC) for up to 18 samples
- Temperature range -170-600°C
- Heating rate: 0.001-100 K/min
- Cooling rate: 0.001-100 K/min
- OIT, TM-DSC
- Atmosphere: oxygen or nitrogen, other gas on request
- Reference material for Cp measurements: sapphire and Al_2O_3
- Sample size up to 2 g



Dynamic Mechanical Analyser (DMA) DMA/SDTA861 (Mettler Toledo)

DMA is used to determine the dynamic properties of materials, such as loss and storage moduli and loss factor. The viscoelastic properties of materials can be characterized as a function of time, temperature, frequency and strain. DMA/SDTA861 from Mettler Toledo is suitable for polymers and polymer blends, elastomers and composites with the wide range of stiffness. Time-temperature superposition analysis feature is available to create a mastercurve for a short- and long-term mechanical behaviour prediction.

Technical details:

- Force range 5 mN to 40 N
- Temperature range -100 to 500°C
- Frequency range 0.001 to 1000 Hz
- Displacement range 5 nm to 1.6 mm



The tests can be run in three modes:

- Shear
- tension
- three-point bending (max 300 Hz)

Dynamic Mechanical Analyser (DMA) PerkinElmer Pyris Diamond

DMA is used to determine the dynamic properties of materials, such as loss and storage moduli, loss factor and the stability of materials. The elastic, viscous and viscoelastic properties of materials can be characterized as a function of time, temperature, frequency and strain. PerkinElmer Pyris Diamond DMA is suitable for polymers and polymer blends, elastomers and composites.

Technical details:

- Sample modulus: $10^3 - 10^{12}$ Pa
- Frequency: 0.01 – 100 Hz
- Temperature: $-150 - 600^{\circ}\text{C}$
- Maximum load: static ± 10 N and dynamic ± 8 N



The tests can be run in four modes:

- Bending
- Tensile
- Shear
- Compression

Thermogravimetric Analyser (TGA) Netzsch TG 209 F3 Tarsus

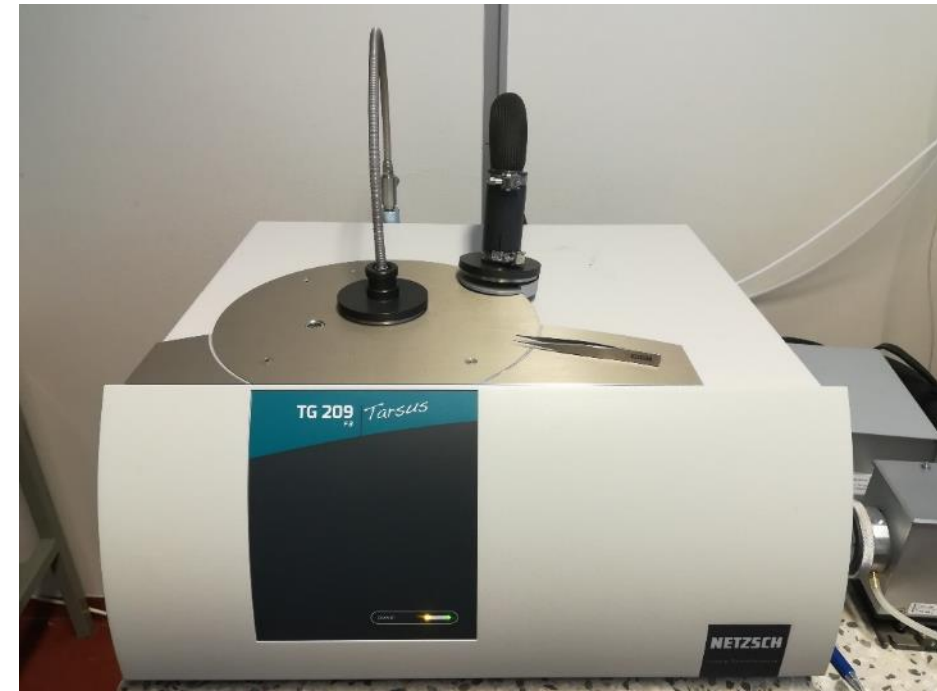
In thermogravimetry (TG) weight changes are measured as function of temperature to perform compositional analysis and to determine kinetics of decomposition. Examples of TG applications: mass changes, decomposition temperatures, dehydroxilation, corrosion/oxidation, thermal stability, reduction studies, composition, filler content.

TGA can be connected to FTIR for simultaneous evolved gas analysis, which allows identifying gaseous products of reactions occurring during the TGA measurement

.

Technical details:

- Temperature range RT to 1000°C
- Temperature resolution 0.001 K
- Heating/cooling rate 0.001 – 100 K/min
- TG resolution 0,1 µg
- Atmosphere: N₂, air, other gas on request



Simultaneous Thermal Analyzer (STA) Netzsch STA 409

Thermal analysis provides various methods in which physical and chemical properties of a material are measured as a function of temperature. In thermogravimetry (TG) weight changes are measured as function of temperature to perform compositional analysis and to determine kinetics of decomposition. Differential Thermal Analysis (DTA)/Differential Scanning Calorimetry (DSC) measures physical and chemical transitions, e.g. melting and curing of polymers.

Technical details:

- Simultaneous TG and DTA/DSC measurements
- Temperature range: RT to 1650°C in TG and DTA mode
- Temperature range: RT to 1400°C in DSC mode
- Cp value measurements in DSC mode up to 1400 °C
- Samples weighing up to 20 g



Laser flash analysis (LFA)

Netzsch LFA 467

LFA is device which measures thermal diffusivity of sample using xenon flash as the heat source. If sample's density and specific heat capacity is defined thermal conductivity of sample can be calculated.

Sample's bottom surface is heated by short heat pulse. This pulse travels through samples thickness and is detected on top surface by IR-detector. Samples can be measured in one or multiple temperatures from -100°C-500°C range. LFA technique is best suitable for materials with ~ 0.1 -2000 W/(m*K) thermal conductivity.

Technical details:

- Measuring ranges:
 - Temperature: -100°C...500°C
 - Thermal diffusivity: 0.01 mm²/s to 1000 mm²/s
 - Thermal conductivity: < 0.1 W/(mK) to 2000 W/(mK)
- Samples:
 - up to 4 large or special samples (25.4mm square or Ø20mm round samples)
 - up to 16 small samples (10 or 12.7 mm square or round samples)
 - Special sample holders for fibers, powders, in-plane, and fluids



Dilatometer

Netzsch DIL 402 Expedis

Dilatometry is used to study length changes in ceramics, glasses, metals, composites, and polymers to reveal information regarding their thermal behavior. The samples can be solid, powders or pastes.

Typically the device is used to measure the coefficient of thermal expansion from sub-zero to high temperatures or to analyze volumetric phase changes or sintering in different atmospheres with temperature or force modulation. Other uses for the device are shrinkage steps, softening point, glass transition, density changes, decomposition temperatures, anisotropic behaviour, and thermal kinetics measurements.

Technical details:

- Measuring range: 50 mm ($\pm 25\,000\ \mu\text{m}$)
- Δl Resolution (over entire measuring range): 0.1 nm
- Initial sample length: 0-52 mm (diameter 12 mm)
- Temperature range : -180 °C to 1600 °C (accuracy 1 K, stability $\pm 0,02\ \text{K}$)
- Heating rates : 0.001 to 100 °C/min
- Force range: 10 mN...3 N
- Gas Atmosphere: Inert, oxidizing, reducing or vacuum.

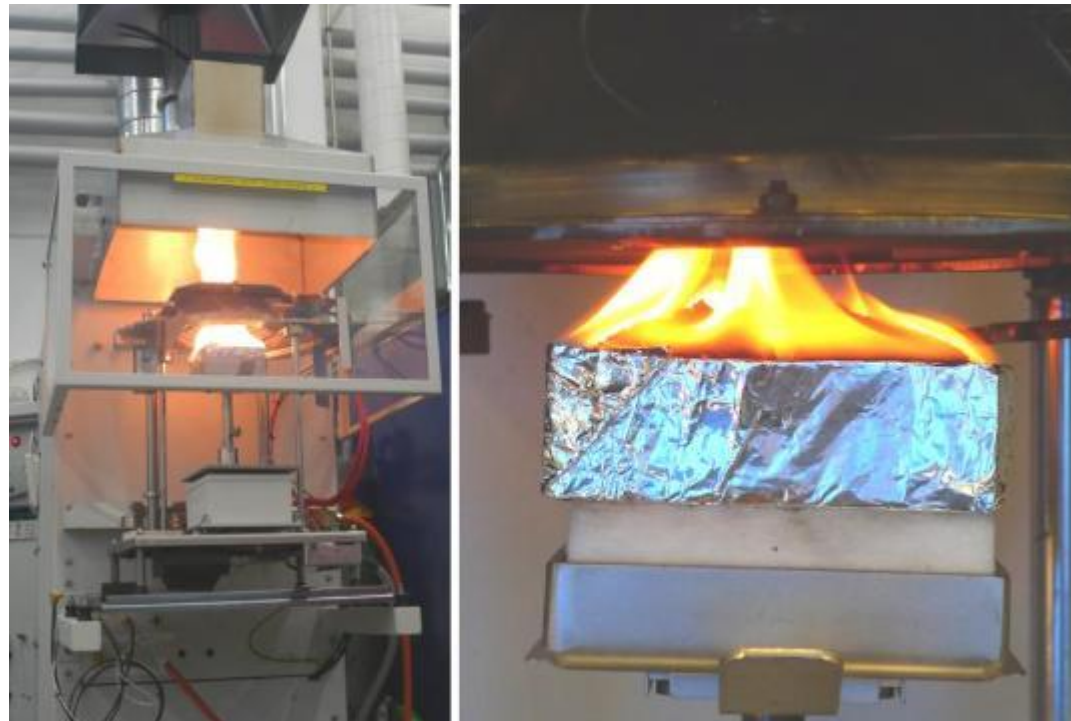


Cone calorimeter

The cone calorimeter (manufacturer Fire Testing Technology) is used to determine the fire resistance of materials. The basic principle of the apparatus is based on the fact that the amount of heat released during the sample combustion is directly related to the amount of oxygen consumed. With cone calorimeter, the following parameters, for example, can be measured: time to ignition, mass loss rate, maximum amount of heat released during combustion and the time when it happens, total heat released as well as the amount of carbon dioxide and carbon monoxide released during the combustion. The equipment is suitable for a wide variety of materials such as coatings, textiles, insulators, construction materials, and other material combinations.

Technical details:

- test area $< 100 \times 100 \text{ mm}^2$
- thickness $< 50 \text{ mm}$
- heat flux $0\text{-}110 \text{ kW/m}^2$



HDT/Vicat

HDT/Vicat Apparatus RAY-RAN/HDV2 to accurately determine the deflection and softening point characteristics of all thermoplastic test specimens.

Heat deflection / distortion test (HDT) is used to evaluate the maximum service temperatures of materials. A standard sized test specimen is subjected to a bending stress, whilst the temperature is raised at a uniform rate. The temperature at which the specified deflection occurs is measured and recorded.

Vicat softening point test (VST) is used to determine the temperature at which the material starts to soften. A specified needle penetrates a specified distance into a sample with a specified load, whilst the temperature is raised at a uniform rate. The temperature at which the sample was penetrated is recorded.



Climate and corrosion testing

Climate testing cabinets

Cold laboratory

Furnaces

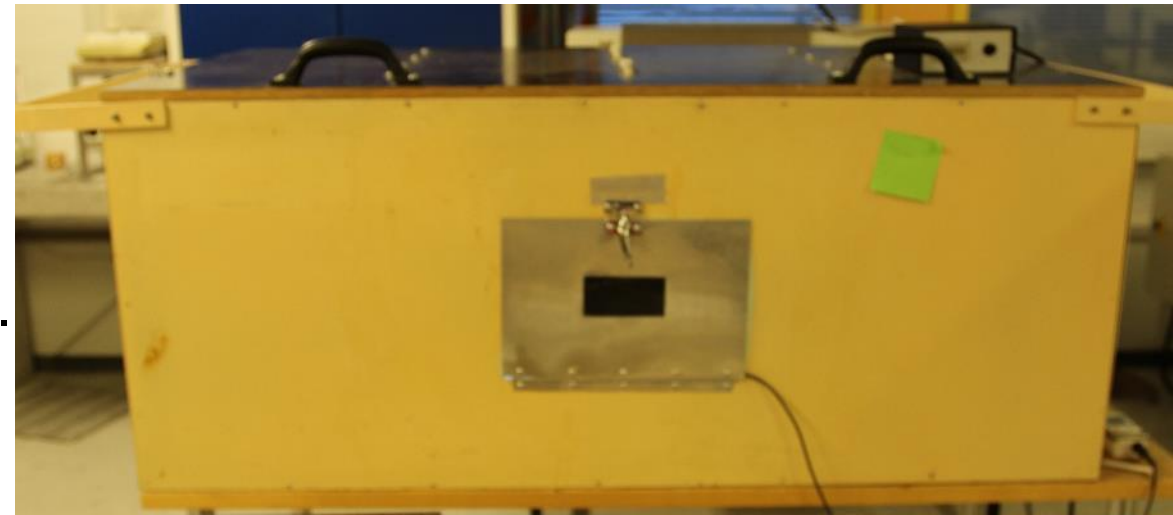
Corrosion testing

UV chamber

The chamber is equipped with four UVA-340 fluorescent tubes (Q-Panel Lab Products) as the radiation source. The spectrum in the chamber is close to sunlight in the critical short wavelength UV region, and the solar cut off is 295 nm.

Technical details:

- Chamber size 1260 x 710 x 450 mm
- The dose rate at
 - the UVB range (290–315 nm) 0.7 W/m²,
 - the UVA range (315–400 nm) 12.1 W/m²,
 - the visible range (400–600 nm) 3.1 W/m²
- 1 h of irradiation corresponds to a 57 kJ/m² dose.



Xenon Weathering system ATLAS SunTest XLS+

The SUNTEST XLS+ is used to check for property changes of materials and products caused by sunlight, temperature and moisture in a short period of time.

The SunTest XLS+ weathering system uses a single Xenon UV-lamp. The specimen chamber is equipped with a black body temperature sensor and precise temperature control to match the ageing to the intended environment.

- 39 x 30 cm (1170 cm²) exposure area



Cold laboratory

The cold laboratory can be used to study for example friction, wear and fatigue at low temperatures. Testing is done by an automated system including an NC-controlled robot with four degrees of freedom (x, y, z and rotation around the z-axis). Data is collected with two 3D force cells and is analysed with LabView. The cold laboratory is used for example to study car and bicycle tires, ice hockey sticks and shoe soles.

Technical details:

- Laboratory temperature can be adjusted accurately between +20...-40°C
- The movement range of the robot is 4 meters in the longitudinal direction, about 1 meter in the horizontal direction and about 80 cm in the vertical direction. There are both mechanical and electrical safety limits.
- Maximum speed 15 m/s, but may be lower since it depends on vertical load and friction of the surfaces
- Maximum vertical load 6 kN
- Two grippers, one for small specimens and one circular gripper. Design of new grippers for special cases is possible.

Furnaces

Material Science has several furnaces for example for heat treatments. These are used to produce components with demanded strength, hardness, porosity, pore size distribution and wanted functional properties from shaped green state ceramics. There are high temperature furnaces especially for ceramic specimens. We have two air atmosphere chamber furnaces and one furnace with inert atmosphere.



High Temperature Furnaces ENTECH SF6 (1990, 1995)

- maximum temperature 1650-1700°C
- chamber size: 200mm x 200mm x 350mm
- maximum allowed heating rate up to 1600°C is 20°C/min
- cooling rate for empty furnace with closed door
 - 1600-1100°C 50°C/min
 - 1100-600°C 17°C/min
 - 600-200°C 7°C/min
- Limitations for specimen
 - metallic and ceramic materials max T around 1000°C
 - maximum specimen 180 mm x 180 mm x 300 mm; maximum weight 4 kg

Inert atmosphere furnace ELATEC

Three different heating element configuration and atmosphere possibilities.

- Graphite heating elements:
 - Atmosphere: vacuum or inert gas up to 100 Pa pressure
- Kanthal heating element
 - Atmosphere: vacuum (1Pa-1100°C) or in inert gas up to 150 Pa pressure (1600°C)
- Metallic heating elements
 - Atmosphere: vacuum or inert gas up to 150 Pa pressure.

Furnaces

Nabertherm VHT 8/22-GR

Chamber

- 8 liters (170x240x200) or with Graphite process box 3 liters (120x210x150)
- Max. Charge 5 kg

Max. Temperature 2200 C

- Heating speed max. 600 K/h min 1 K/h (empty furnace)
- Cooling speed max. appx. 1900 K/h (from 2200 in protective gas)

Vacuum & Gas

- 2-stage rotary vane pump Leybold Trivac D16B $< 5 \times 10^{-2}$ mbar
- 2 gas connections with mass flow controllers
 - Argon and Nitrogen
 - Gas flow rate 50-500 l/h with filling time appx. 60 s
 - Partial pressure 10-1000 mbar (abs.)

Automatic controller (Siemens S7 PLC) for vacuum, gas and heating



VHT 8/18-GR with additional equipment



VHT 8/22-GR

Corrosion analysis

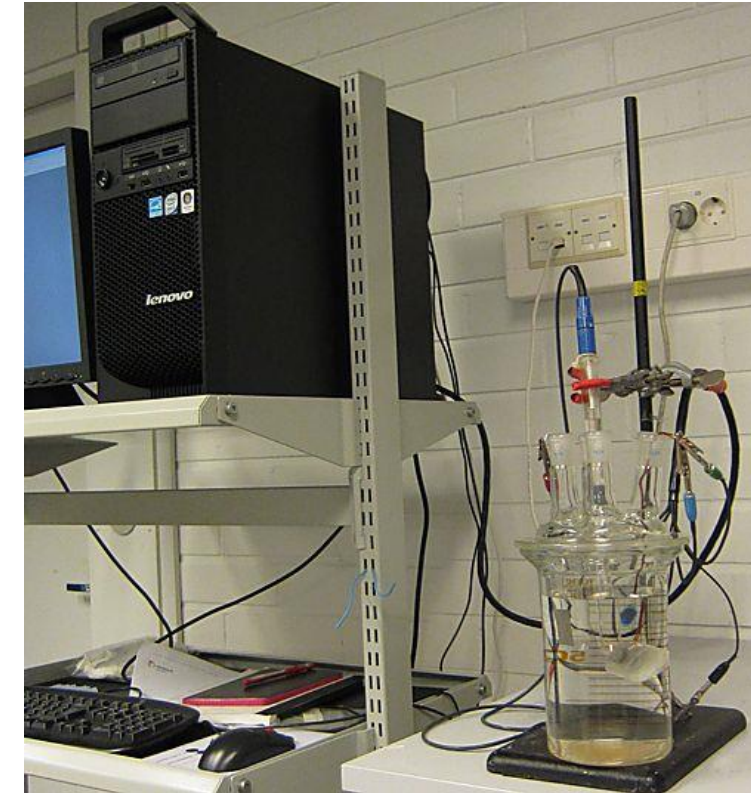
Several devices for different corrosion-monitoring techniques

- three computer controlled potentiostatic study devices for polarization measuring
- device for resting potential measurements
- salt spray test equipment

Corrosion monitoring can also be performed in temperature cabinets. In addition to the corrosion analysis there is possibility to use SEM with EDS analysis and X-ray diffraction device.

Polarization and resting potential measurements are electrochemical techniques in corrosion analysis. Corrosion rates and charge transfer properties of an electrochemical system can rapidly be predicted from impedance data and from potentiodynamic techniques. Corrosion rate depends primarily on factors relating to the electrochemical reaction, temperature, electrode material, surface area and chemical environment.

Measurements provide information about corrosion reactions. They can be monitored or driven at the surface of a desired metal sample, and a variety of characteristics related to the metal/environment pairing can be determined. Examples of characteristics of interest include open circuit or corrosion potential, instantaneous corrosion rate, passivation behavior, pitting potential and susceptibility, and galvanic corrosion behavior of dissimilar metal pairs. Salt spray tests are type of accelerated corrosion test.



Computer controlled potentiostatic study device for polarization measuring

Software

J-MatPro

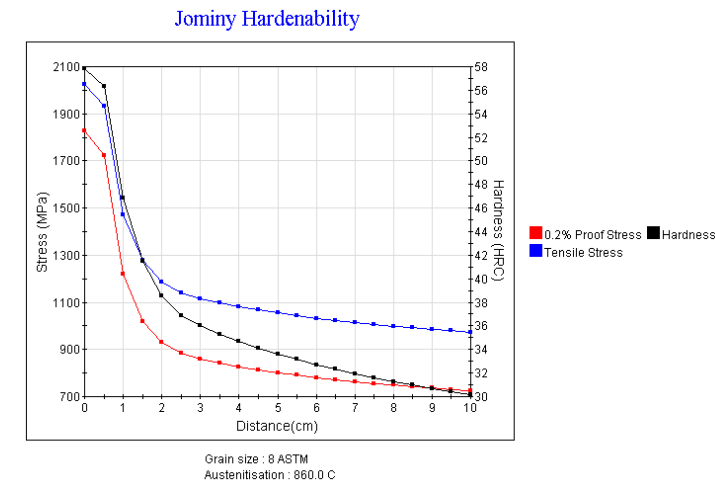
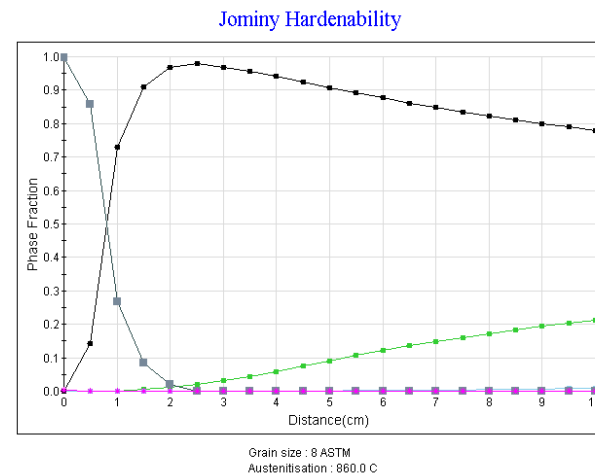
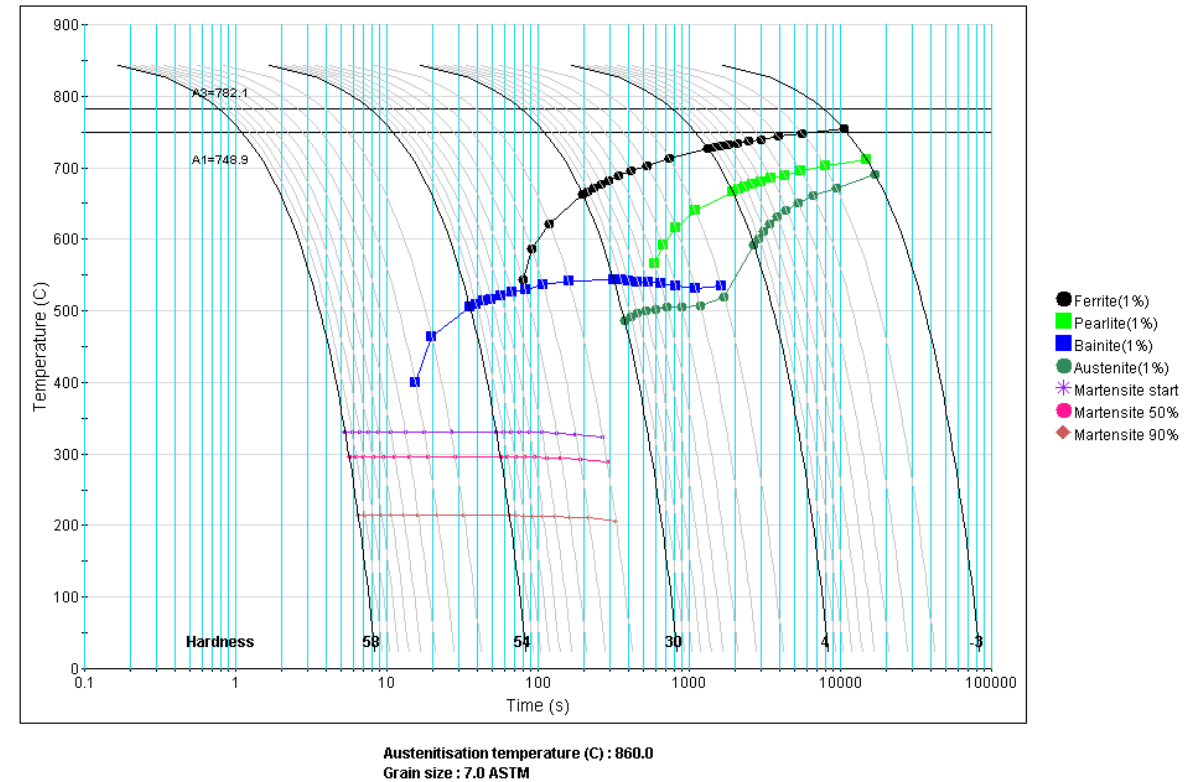
Prior austenite reconstruction algorithm

Numerical modeling

JMatPro

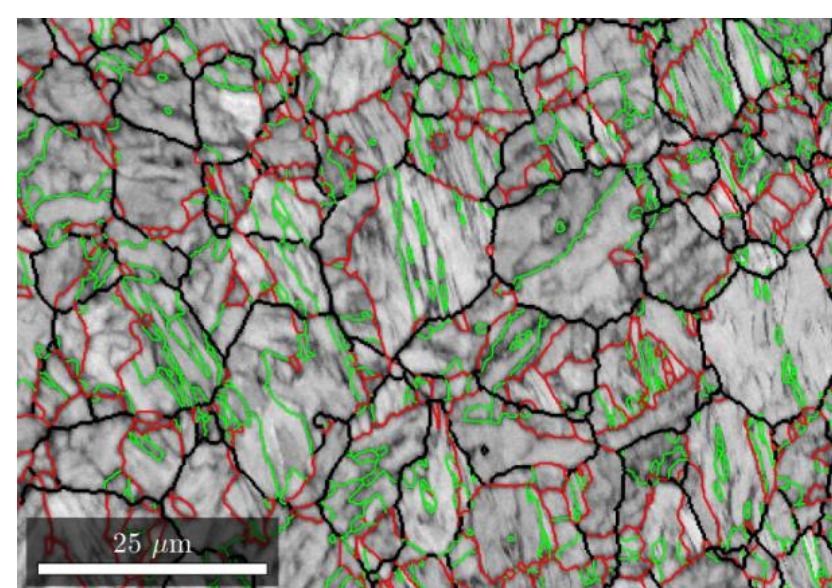
JMatPro is a commercial software package which is based on CALPHAD – method and extended by models which allow calculation of materials properties.

- It is able to calculate phase transformation diagrams, CCT/TTT-diagrams and for generation of materials property data for FE-simulation, like casting-, forming- and heat-treatment simulations
- Modules: Aluminium, General Steel, Stainless Steels, and Cast Iron
- Academic licence: used extensively in teaching and in academic studies



Prior austenite reconstruction algorithm

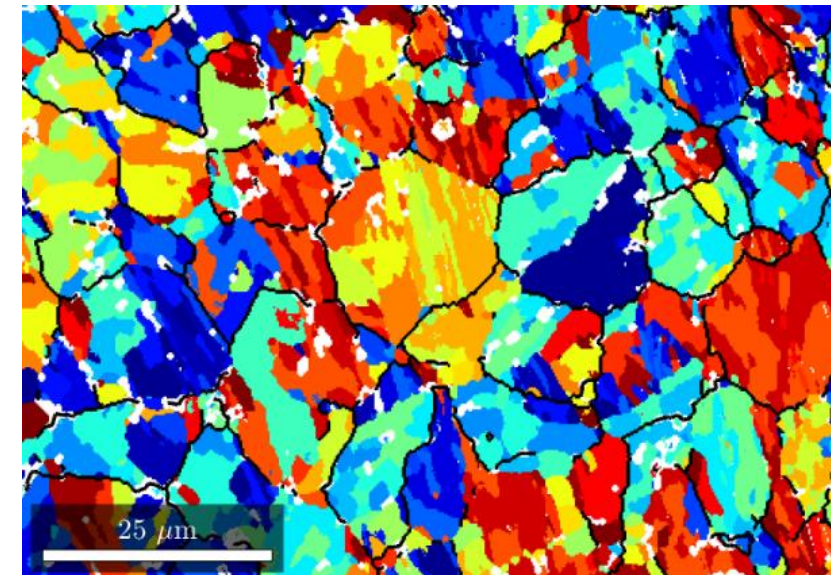
- Reconstructs the orientation map of a high-temperature austenitic microstructure based on a bainitic or martensitic orientation map produced by EBSD
- Provides information is extremely difficult to measure in-situ
- The result can be used to analyze the crystallographic texture and morphology of the high-temperature austenitic microstructure



Block, packet and prior austenite grain boundaries



Reconstructed austenite orientation map



Martensite variant selection map

Numerical modeling

Wide range of numerical analysis mainly based on finite element (FE) method.

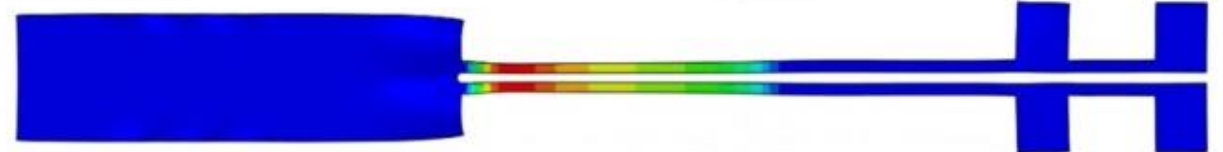
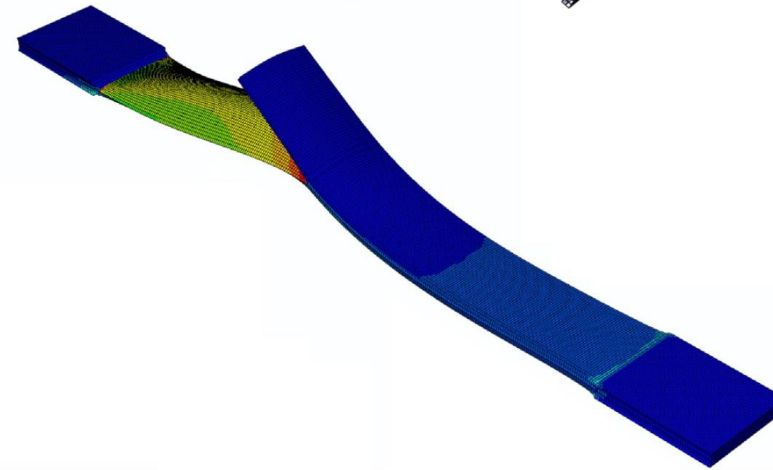
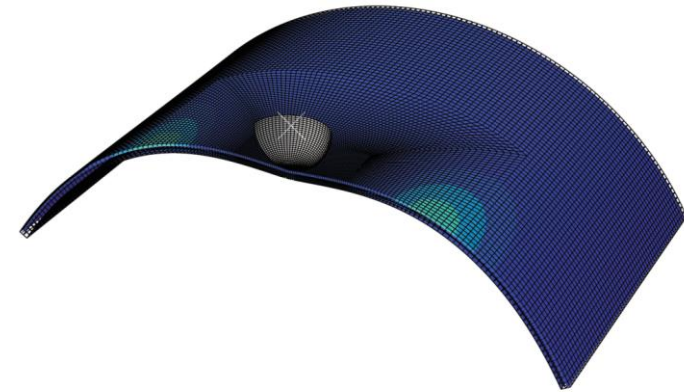
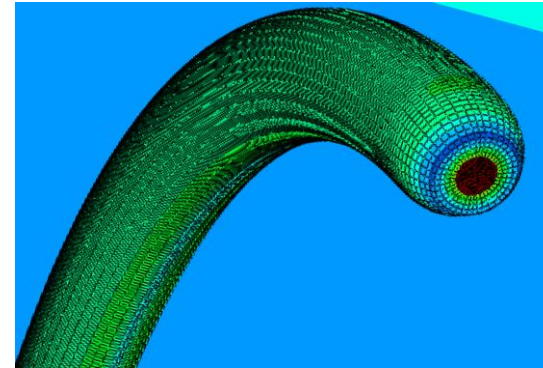
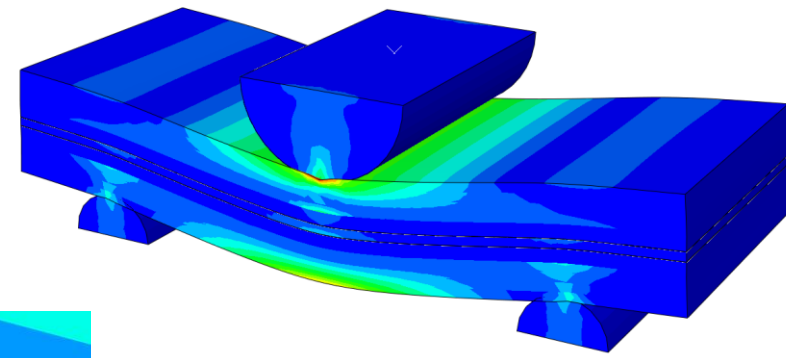
- FE software Abaqus (Simulia)

Specialized in fracture and damage:

- Delamination and debond
- Impact
- Aging

Materials:

- Composites
- Adhesive bonded joints
- Elastomers
- Metals



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