

# Tampere Wear Center Research equipment



# Tampere Wear Center Research equipment

## Wear testing

- Pin-on-disk/Ball-on-disk, Crushing pin-on-disk, Uniaxial crusher, Dual pivoted jaw crusher, Impeller-tumbler, High-speed slurry-pot type erosion tester, Erosion tester, Slurry erosion-corrosion tester, Cavitation erosion tester, High velocity particle impactor, Ball-on-block, Hammer mill, Block-on-ring, Rubber wheel abrasion testers

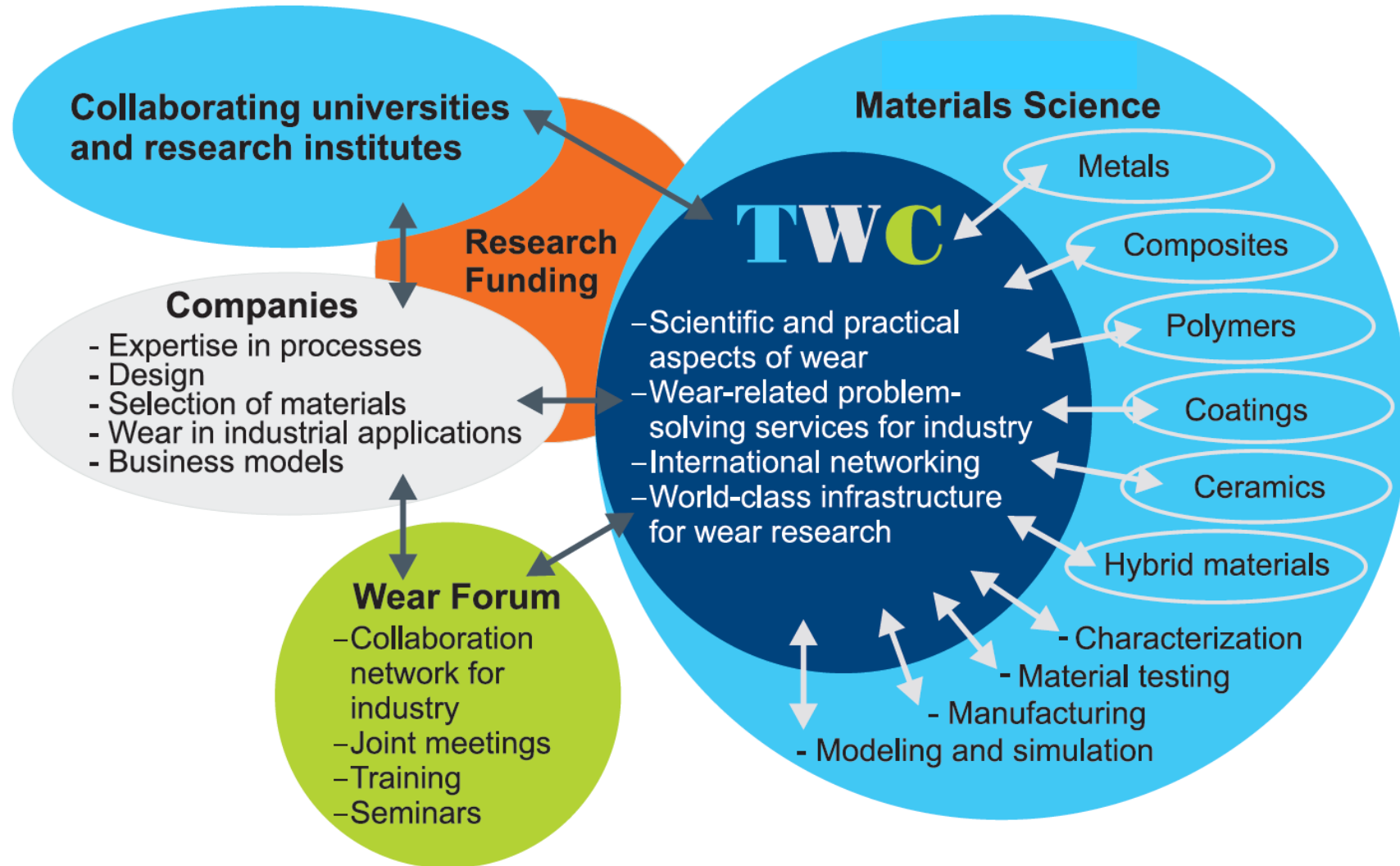
## Tribology and machine elements test rigs

- Test rigs for journal, thrust, and rolling bearings, FZG, Twin-disc test rig, Mini traction machine, Fretting wear and fatigue test rigs, Vibration Testing



# Tampere Wear Center

- Concentrates on both scientific and practical aspects of wear and tribology
- Strengthens research in the field of wear and tribology of materials
- Special expertise areas heavy abrasion, impact wear, fretting and tribology of machine elements, such as gears, bearings, brakes, seals, and frictional joints



# Wear testing

Pin-on-disk/Ball-on-disk

Crushing pin-on-disk

Uniaxial crusher

Dual pivoted jaw crusher

Impeller-tumbler

High-speed slurry-pot type erosion tester

Erosion tester

Slurry erosion-corrosion tester

Cavitation erosion tester

High velocity particle impactor

Ball-on-block

Hammer mill

Block-on-ring

Rubber wheel abrasion testers



# CETR UMT-2 Pin/Ball-on-disk



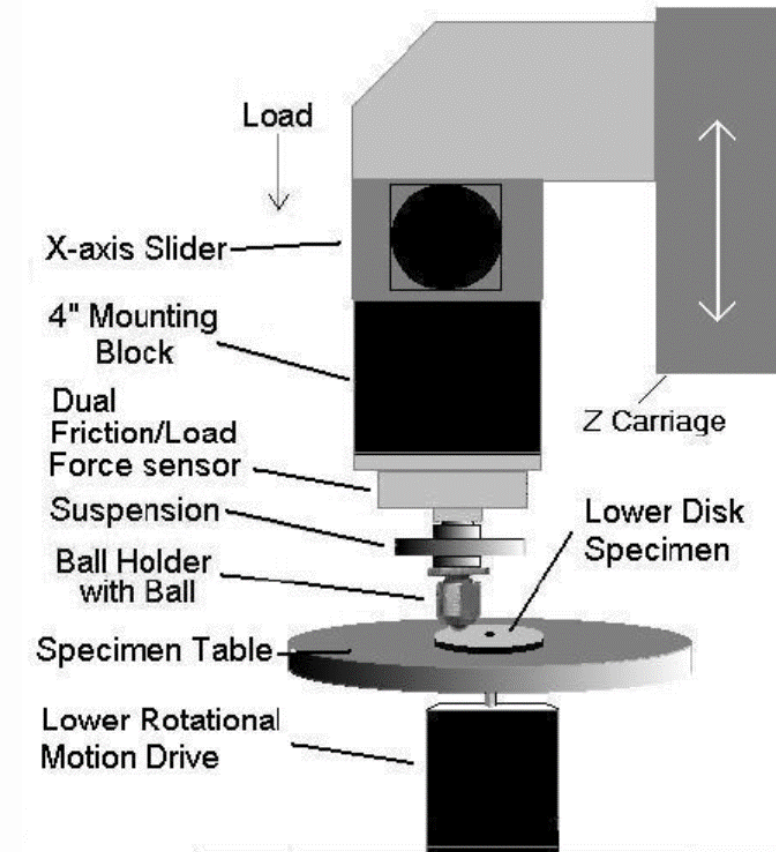
Commercial Pin-on-disk / Ball-on-disk equipment;  
fulfills ASTM G99 –95a standard

Elevated-Temperature Chamber:

- Temperature: -20-350°C
- Revolve disk speed: 0.1 - 1000 rpm
- Max. disk size: 70 mm
- Standard specimens:
  - Pins: Diameter of 6.35 and 10 mm
  - Balls: Diameter of 6.35 and 9.5 mm
- Humidity/Gases Chamber (no controls)
- Possibility to use lubricants
- Humidity control: 5-95%RH

High-Temperature Chamber:

- Temperature up to 1000°C
- Revolve disk speed: 0.1 - 1000 rpm
- Max. disc size: 50 mm
- Standard specimens:
  - Pins: Diameter of 6.35 and 10 mm
  - Balls: Diameter of 6.35 and 9.5 mm



# Crushing Pin-on-disk

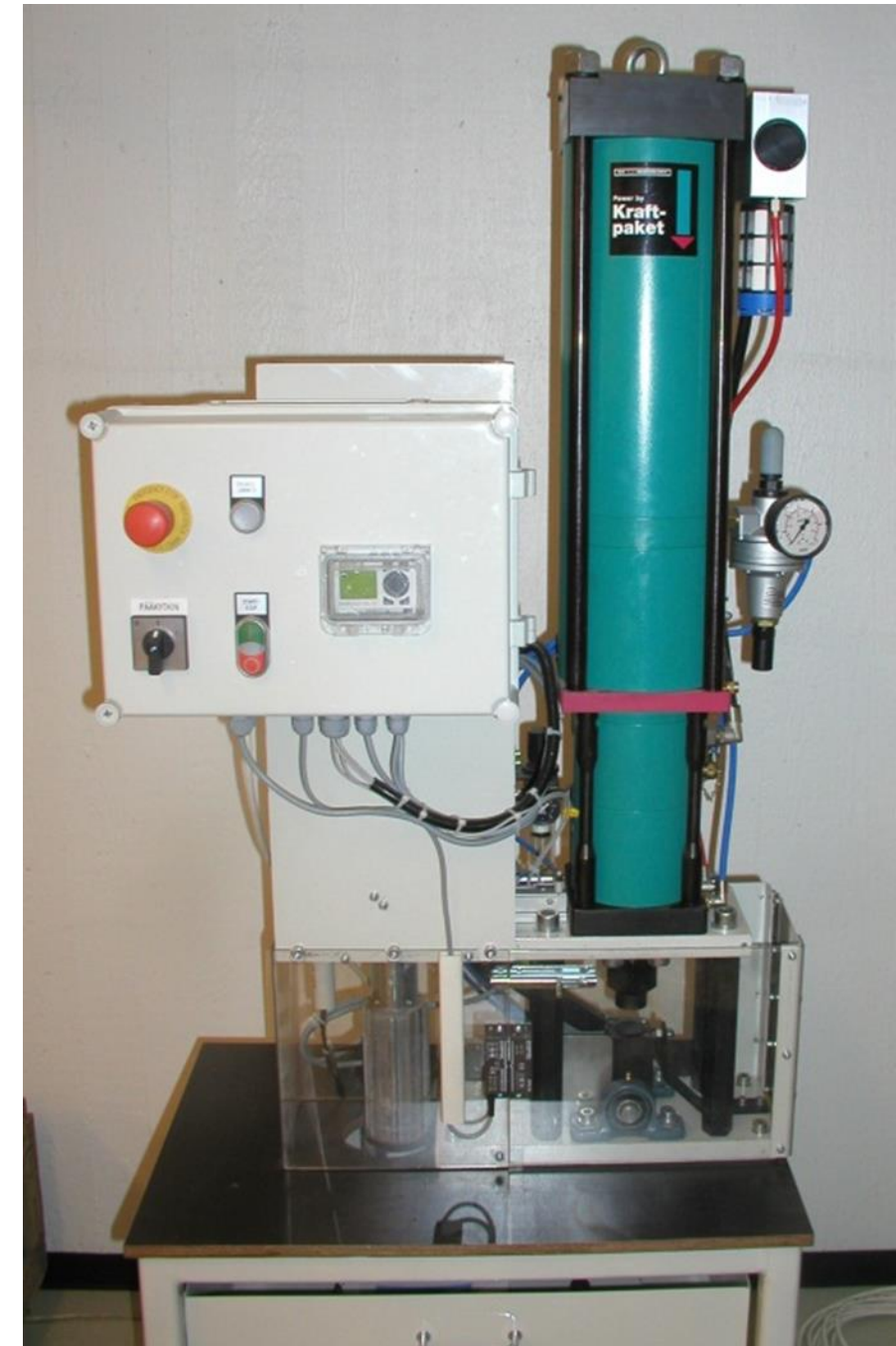
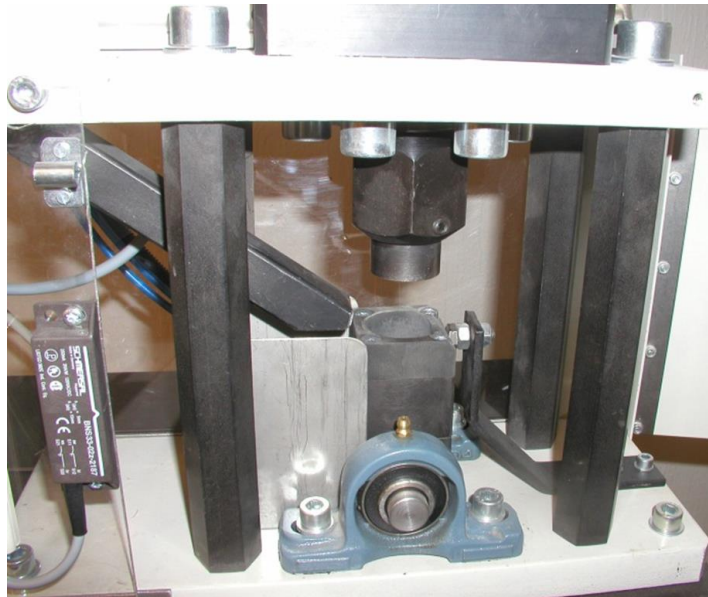
- Pin is repeatedly pressed against the gravel bed and the disk with a pneumatic cylinder (200-500N)
- Pin does not come into direct contact with the disk at any time → wear of the components due to abrasive ploughing and cutting on the pin and disk surfaces
- During the test, the abrasive size decreases at different rates, depending on the pin-disk combination.
- Simulates cone or jaw crusher
- Specimen:
  - Diameter of 36 mm
  - Height of 35 mm
  - Flat area 1000 mm<sup>2</sup>
- Disk:
  - Diameter of 160 mm
  - Thickness of 2-155 mm
  - Rotating velocity control





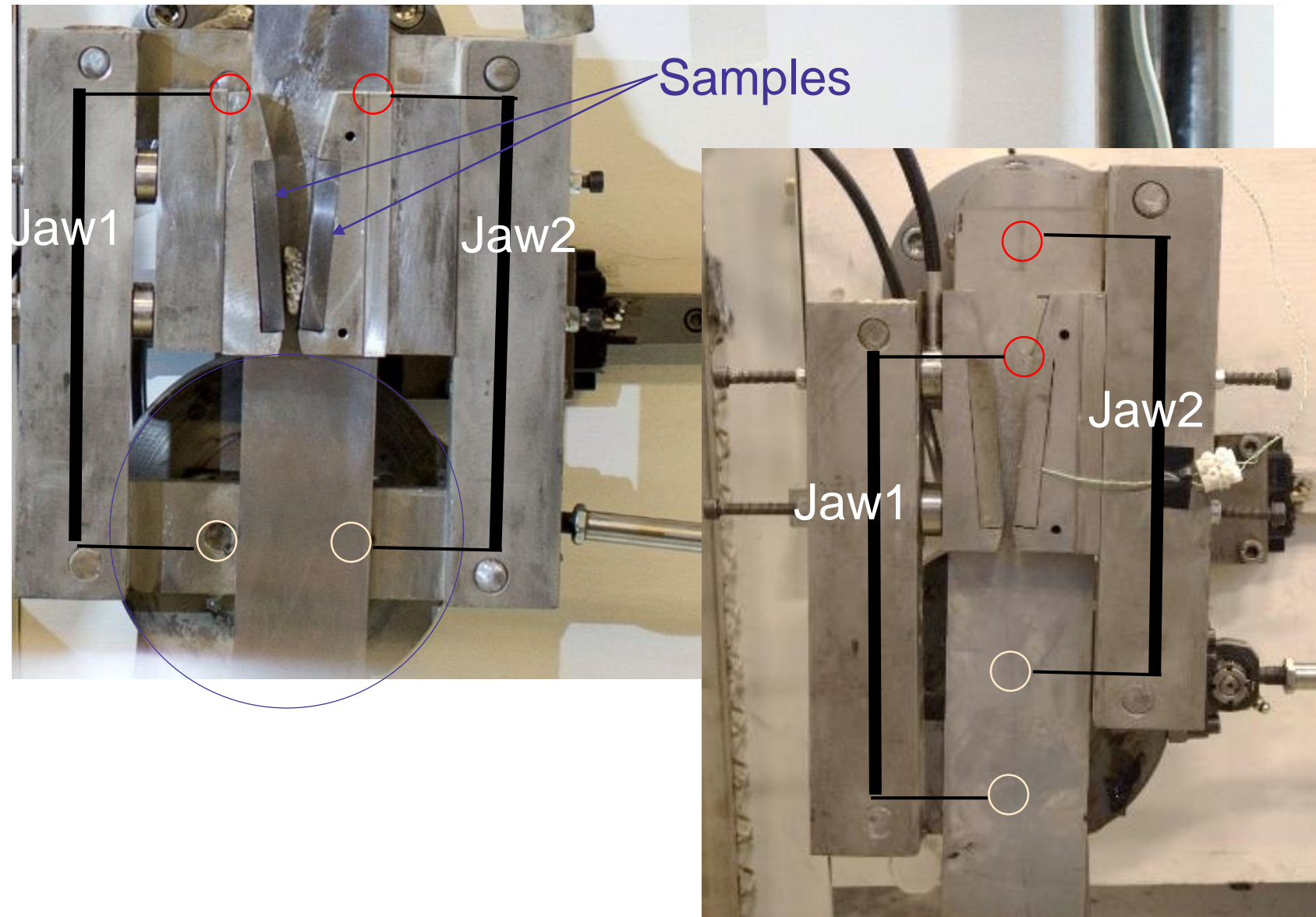
# Uniaxial Crusher

- The equipment crushes the abrasive uniaxially between two specimens with a high pressure
- Controlled amount of the abrasive
- Simulates a mineral crusher
- Specimen: area of 1000mm<sup>2</sup>, height of 35 mm and diameter of 36 mm
- Impacts with the hydraulic cylinder:
  - 6 bar (max) 86 kN
  - 5 bar 69 kN
  - 4 bar 53 kN
  - 3 bar 39 kN
  - 2 bar 23 kN



# Dual pivoted jaw crusher

- Laboratory scale jaw crusher for studying the mechanisms of abrasive wear during mineral crushing
- Key design features:
  - control of jaw movement without changing the test geometry, enabling accurate control of the compression-sliding ratio
  - versatile instrumentation for monitoring the wear processes, including piezoelectric force sensors, high speed video systems, etc.
- Test outcomes
  - wear of both jaw specimen
  - work in Fz and Fy directions
  - feed size reduction to product
- Specimen
  - jaw plate size 75\*25\*10 mm
  - abrasive particle size 6-14 mm





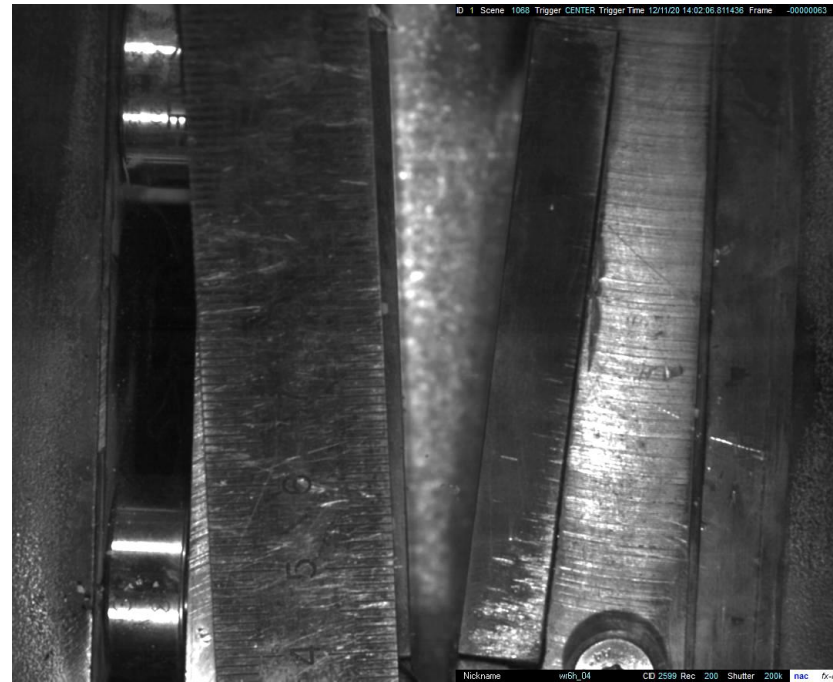
# Movement of jaws with 5°+5° jaw angles



0° frame setup

$\Delta Y = 0.3 \text{ mm}$

$\Delta Z = 3.0 \text{ mm}$



45° frame setup

$\Delta Y = 3.23 \text{ mm}$

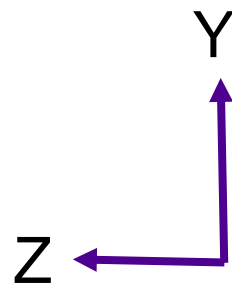
$\Delta Z = 3.27 \text{ mm}$



90° frame setup

$\Delta Y = 24.0 \text{ mm}$

$\Delta Z = 4.98 \text{ mm}$



(high speed video = 20 times slower)

# Impeller-Tumbler Impact-Abrasive Wear Tester

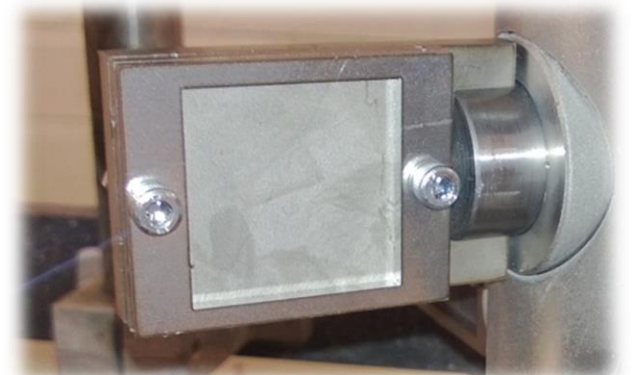
- Simulates wear in mineral handling applications, such as earth moving machinery and impactor plants.
- During the test, an impeller with three samples (75\*25\*10 mm) rotates inside a rotating tumbler filled with gravel.
- Impeller rotating speed up to 700 rpm, tumbler rotating speed up to 120 rpm
- Variables: sample angle, gravel size distribution, type, and amount
- One sample is the reference → changes in mineral composition controllable





# High-speed slurry-pot type erosion tester

- Testing of wear resistant materials in high stress erosive or abrasive wear conditions
  - slurry pumps, mining applications, dredging, loader buckets, containers, etc.
- Testing of mineral abrasiveness in a slurry or in dry conditions
- Key design features:
  - high rotation speed: up to 2000 rpm (20 m/s in the sample tip)
  - large abrasive size: 0-10 mm
  - suitable for testing of metal bars or plates, thick and thin coatings, elastomers, and hybrid materials
  - possibility to edge protection
  - flow conditions vary in 4 sample levels → requires sample rotation
  - variable sample sizes and shapes

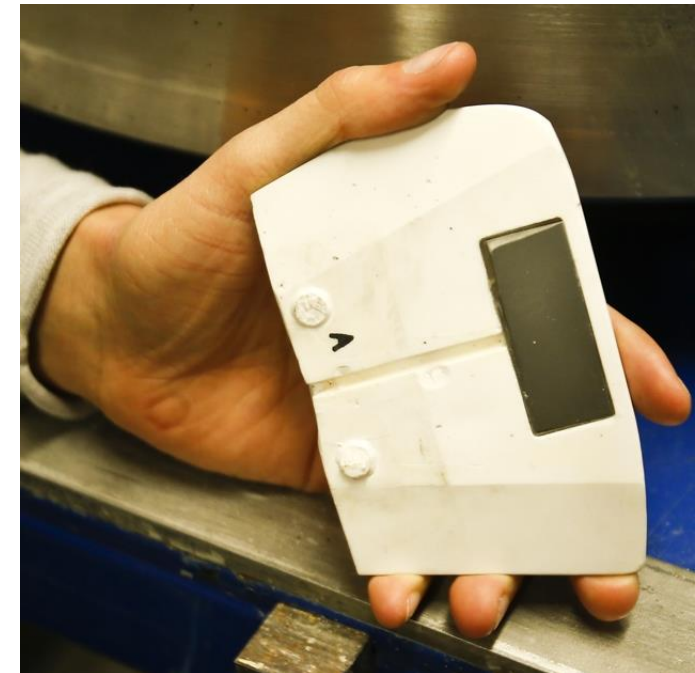




# Slurry erosion-corrosion system



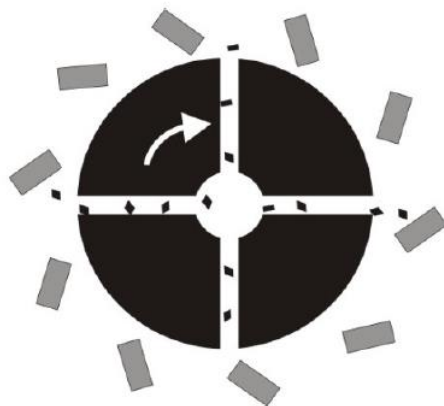
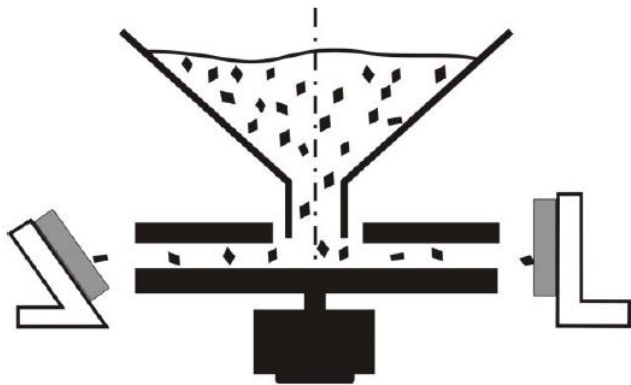
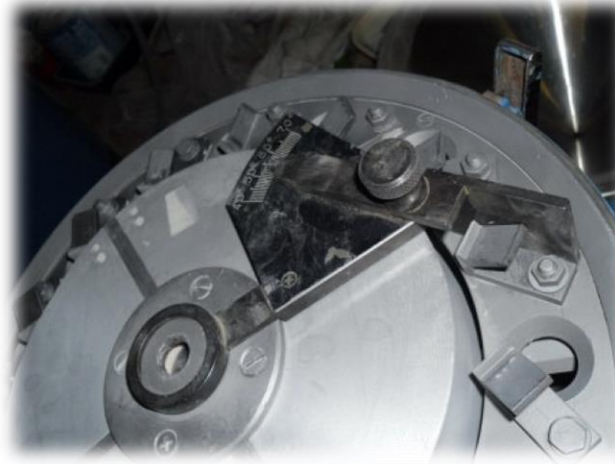
- Possible to determinate slurry erosion with or without corrosion
- Potentiostat for corrosion measurements



# Erosion tester

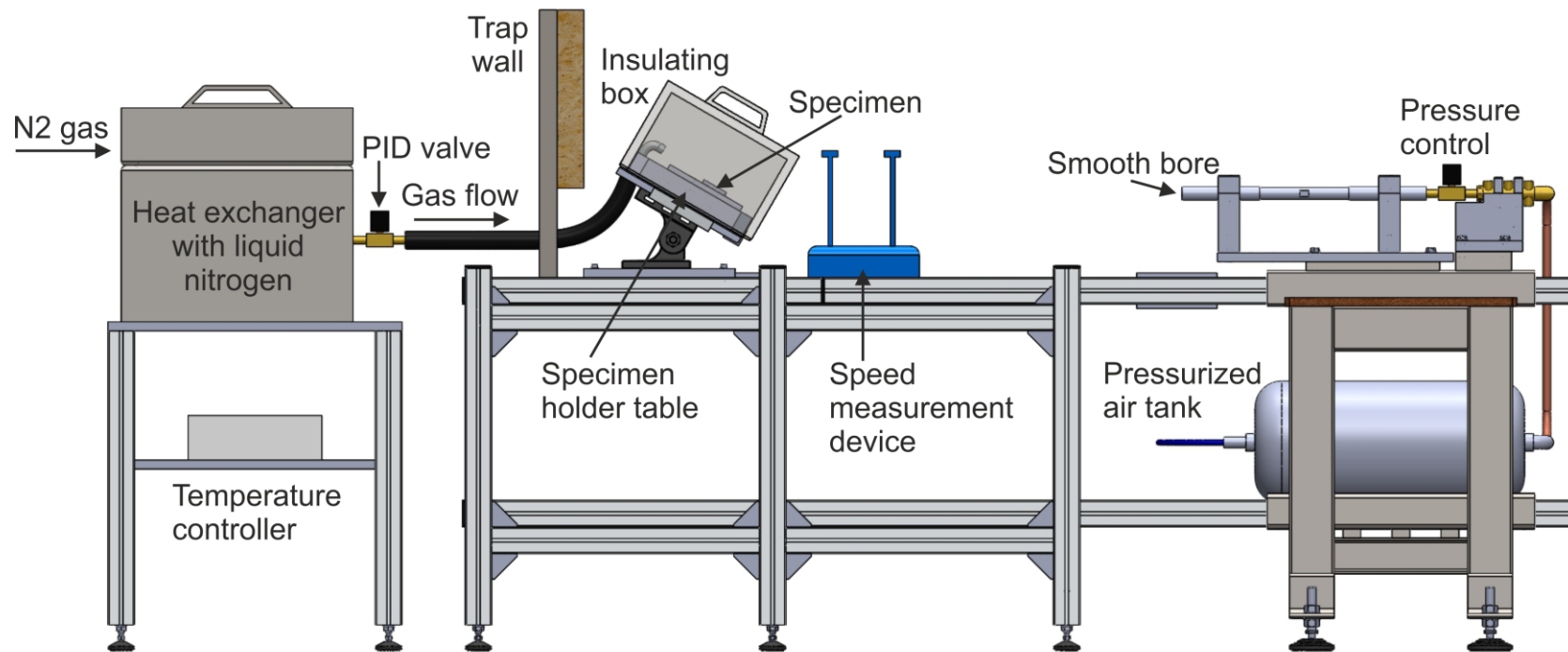
Wear testing of materials and coatings at room temperature with centrifugal accelerator

- Impact angle: 15°, 30°, 45°, 60°, or 90°
- Impact velocity: 0-80 m/s
- Abrasive typically quartz
- Abrasive size: up to 1 mm
- Sample size: 20\*15 mm, thickness 5 mm
- Samples quantity: up to 15 samples





# High velocity particle impactor (HVPI)



Temperature  $-40^{\circ}\text{C}$   
Sample angle  $60^{\circ}$   
Velocity  $\sim 112\text{ m/s}$



- Developed for the model verification and to identify the basic mechanisms influencing the impact wear and failure behavior of materials
- Key design features:
  - various angles and impact energies; projectile speed:  $30\ldots 200\text{ m/s}$
  - suitable for various materials: metals, coatings, elastomers, hybrids, ...
  - projectiles: metallic or ceramic ball bearing balls, cylinders, bullets, and rocks
  - video recording: high speed camera NAC MEMRECAM up to  $80\,000\text{ fps}$  or LaVision StrainMaster 3D DIC systems (high and low rate)
  - cooling setup: temperatures down to  $-80^{\circ}\text{C}$  can be reached; cooling with nitrogen gas, impact happens in ambient air



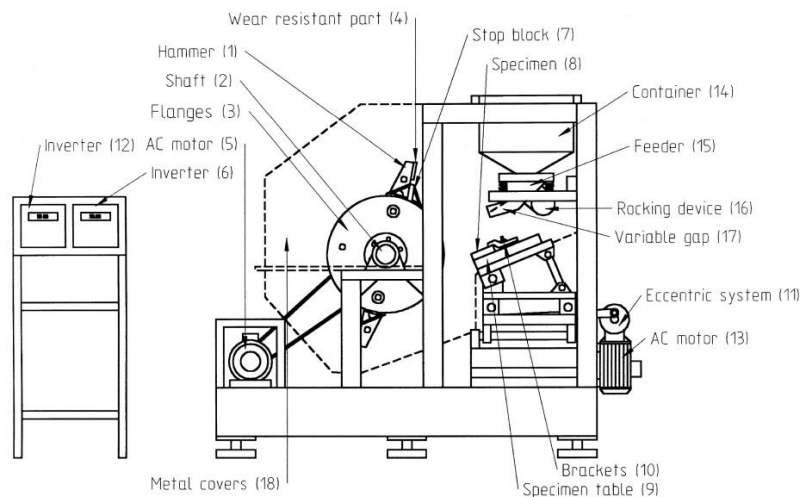
# Ball-On-Block Impact Wear Testing Device

- Ball-on-block is a high-energy impact wear testing device that produces repeatedly high-energy impacts to the surface of the specimen
- Impacts are created by shooting a ball to the specimen using a pneumatic cylinder
- Simulates wear on a SAG-mill
- Ball:
  - mass 8 kg and diameter 125 mm
  - Impact velocity 8-12 m/s ( $E_k = 256 \text{ J} - 576 \text{ J}$ )
  - material for example tempering steel
- Specimen:
  - size 200x200x75 mm or 200x200x50 mm
  - various materials tested such as steels, rubbers, metal matrix composites, hard metals



# Hammer-mill

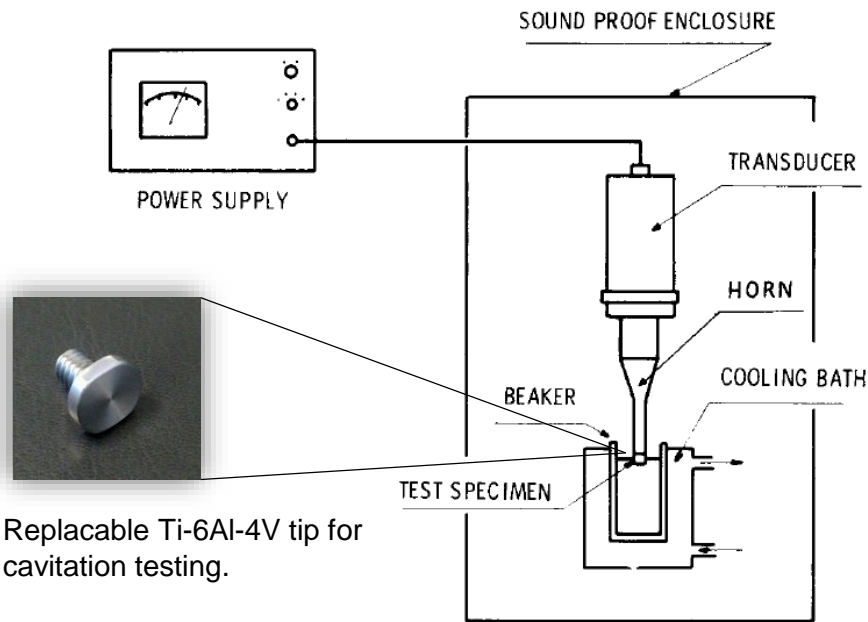
- Two rotating hammers
- The abrasive is fed between the hammer and the specimen from a container through a feeder tube
- Hammers:
  - Speed: 5,1-9,0 m/s
  - Impact energy: 21,9-66,9
  - Typical speed 7 m/s and impact energy 50 J
- Specimen:
  - 80mm x 80mm – 250mm x 250mm
  - Thickness 15-45mm



# Test Method for Cavitation Erosion Using Vibratory Apparatus

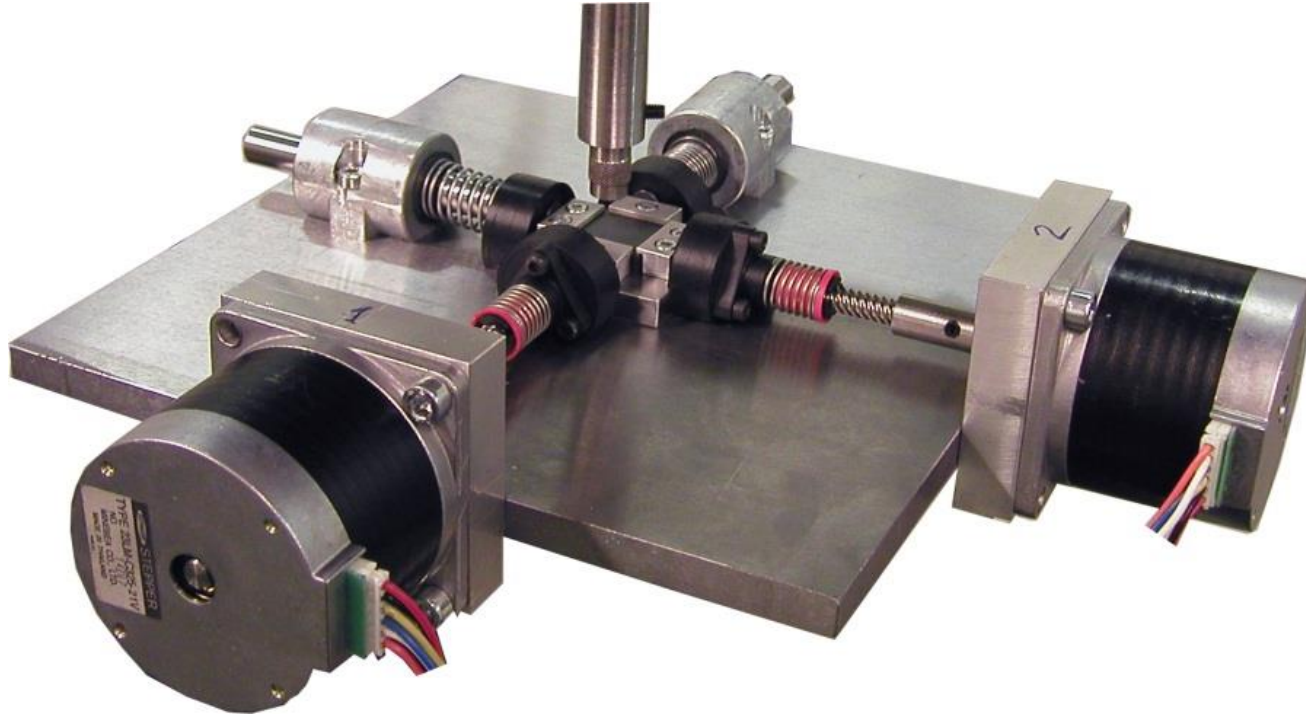
- Standard test ASTM G32-10
- Vibra-Cell VCX-500 ultrasonic processor
  - Allows process control and monitoring from 1°C to 100°C

| Test parameters    |                  |
|--------------------|------------------|
| Frequency          | 20 kHz           |
| Amplitude          | 50 $\mu\text{m}$ |
| Distance to sample | 0.6 $\pm$ 0.1 mm |
| Water temperature  | 25 $\pm$ 1 °C    |
| Tip diameter       | 13 mm            |

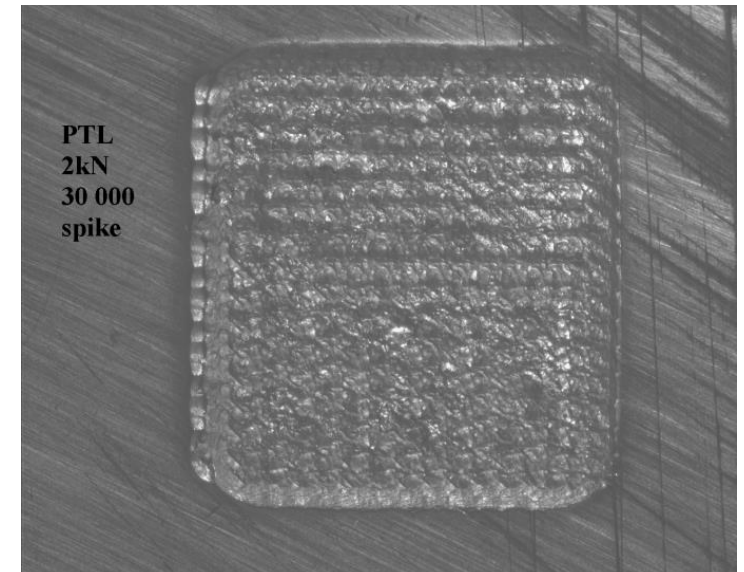
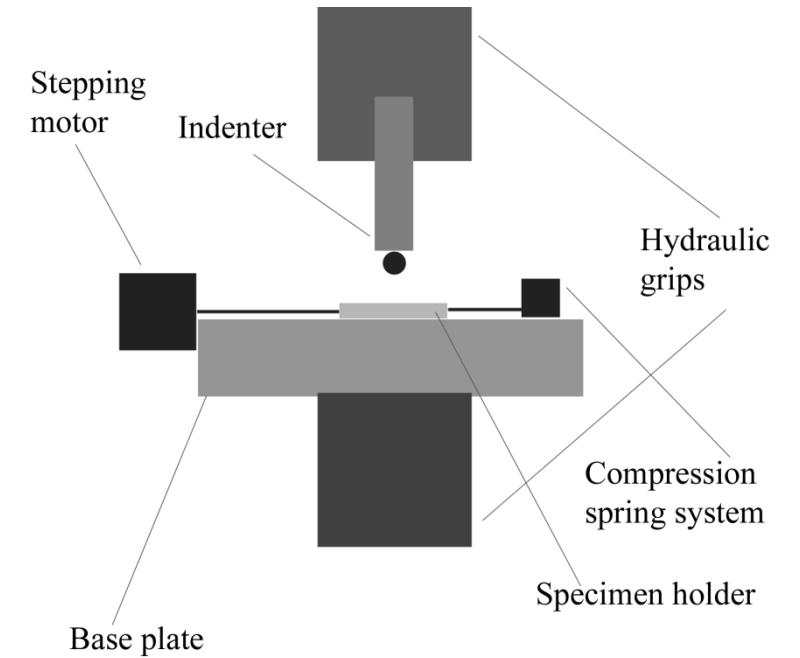




# Surface fatigue wear



- Attached to Servohydraulic Instron mechanical testing machine
- Holder moves after every step
- Intender ball, cylinder or spike
- Area covered: 15 x 15 mm



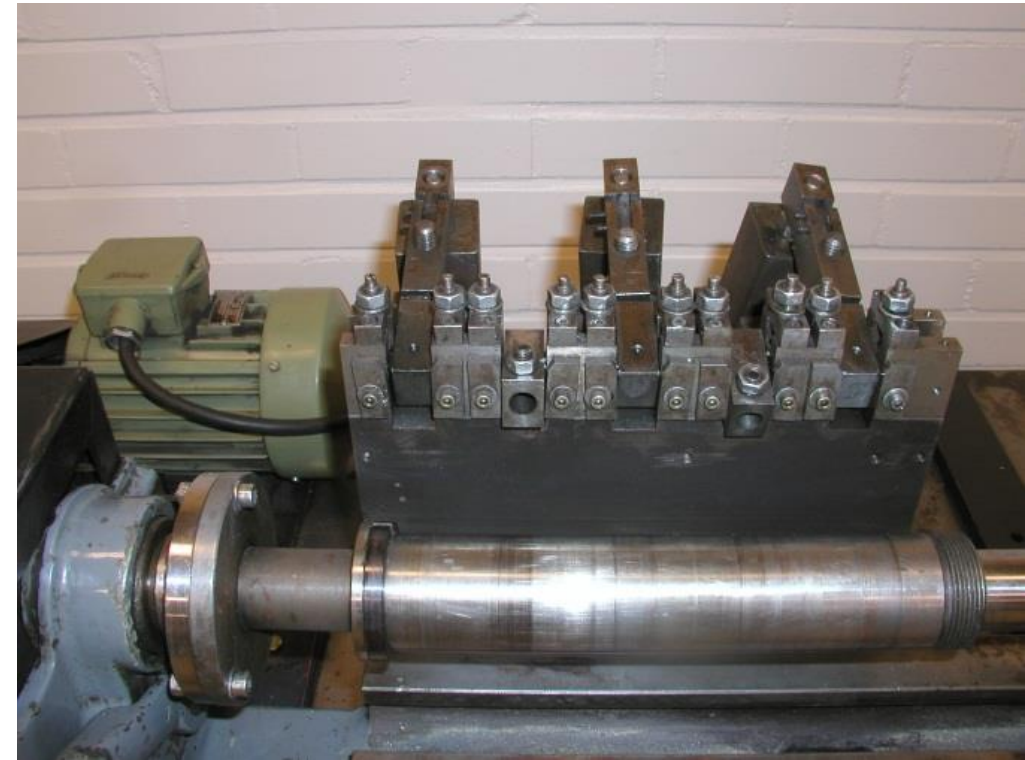
# Other wear testing equipment



Dry Sand Rubber Wheel  
Abrasion Testing Device



Slurry Abrasion Testing Device



Block-on-Ring

# Tribology and machine elements test rigs

Journal bearing test rig

Thrust bearing test rig

Gears and lubricants (FZG) test device

Large-scale, full power bevel gear test rig –  
2 MW closed loop

Rolling bearing test rig

High pressure twin-disc test rig

Fretting wear and fatigue test rig –  
complete contact, bolted joint

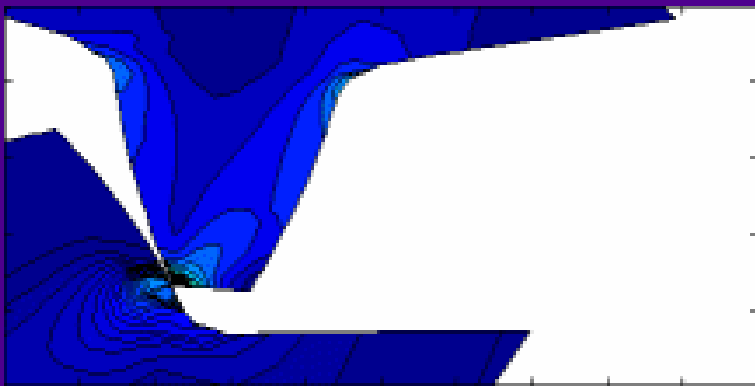
Fretting friction, wear and cracking test  
rig – flat-on-flat contact

Tribometer -PCS -MTM2

Advanced vibration and noise instruments

Basic tribology equipment

- Viscometer
- Microscopes
- Surface profilers
- Pin-on-disc test device





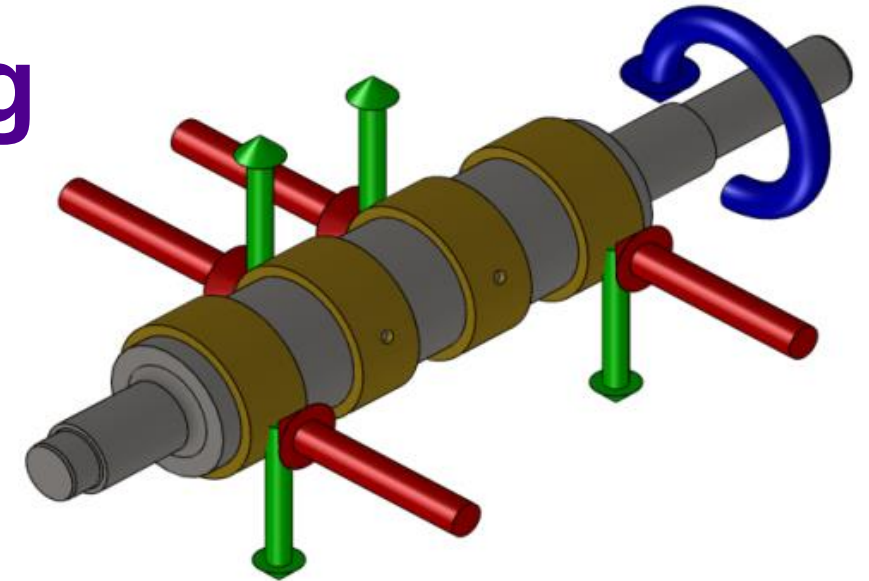
# Journal bearing test rig

## Test targets – evaluation of bearing performance

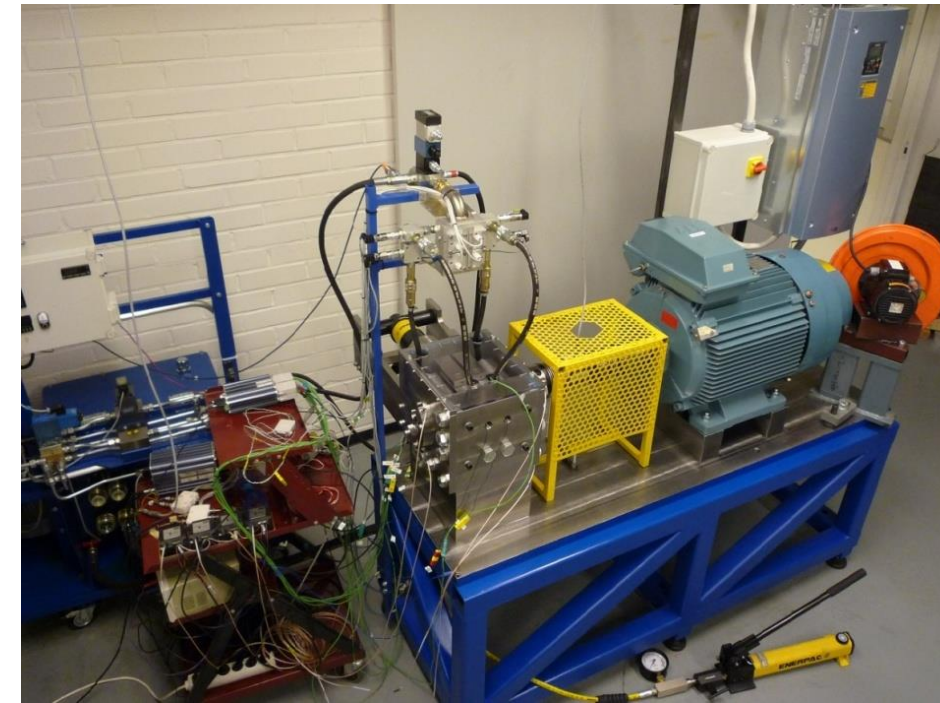
- friction, power loss
- failure modes, life
- lubricants, lubrication condition
- temperatures, fluid film pressures
- bearing materials and configurations

## Specifications:

- sliding speed 0.05 ... 16 m/s
- projected pressure 0 ... 15 MPa
- oil temperature, pressure and flow controls
- shaft misalignment control
- no support bearings
- automated operation and sequences



Test bearings and acting forces



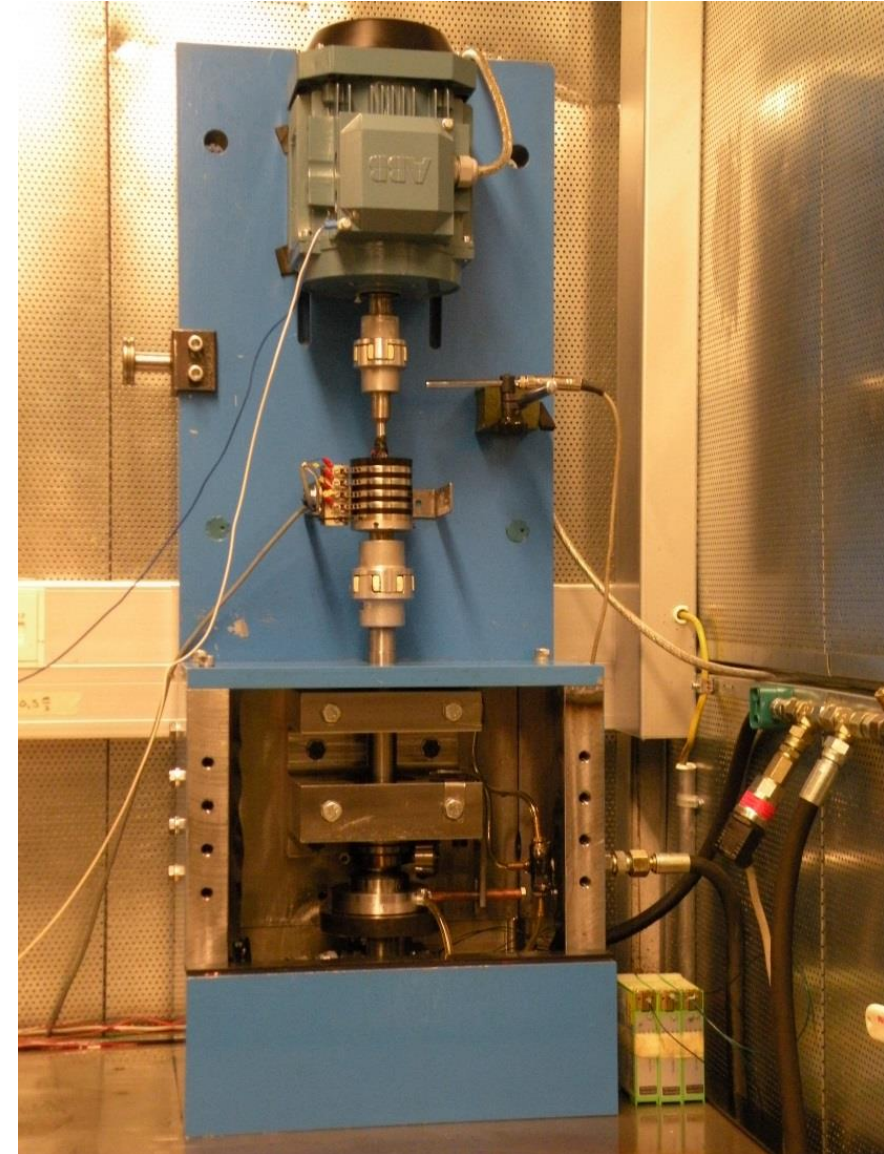
# Thrust bearing test rig

## Test targets: evaluation of thrust bearing performance

- friction and power loss
- load capacity
- bearing materials and configurations
- failure modes

## Specifications:

- rotating speed 0 – 2000 rpm
- external lubrication unit with oil filtering and temperature, flow and pressure control





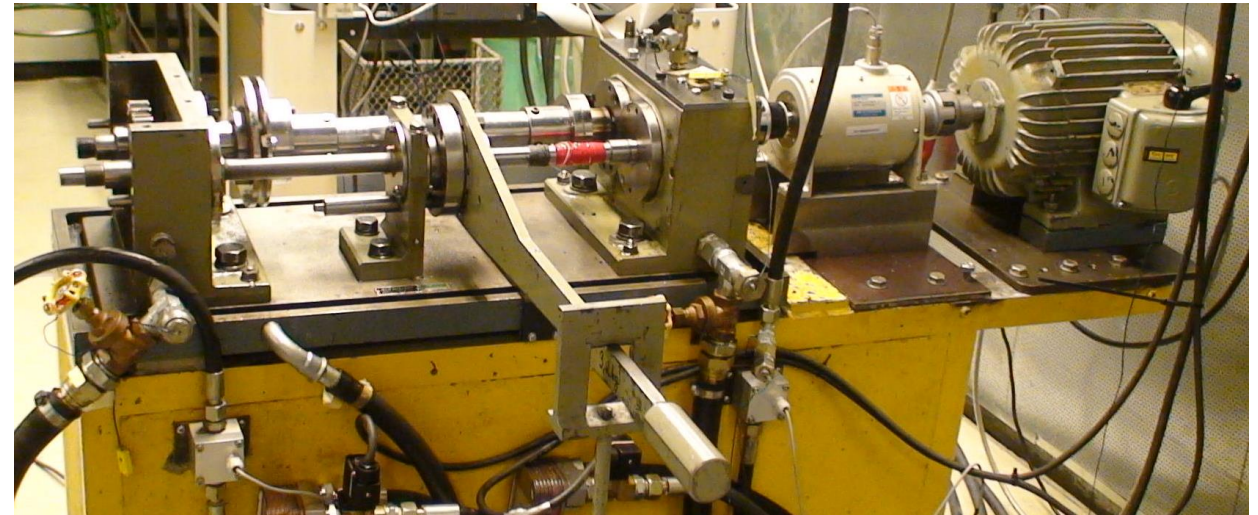
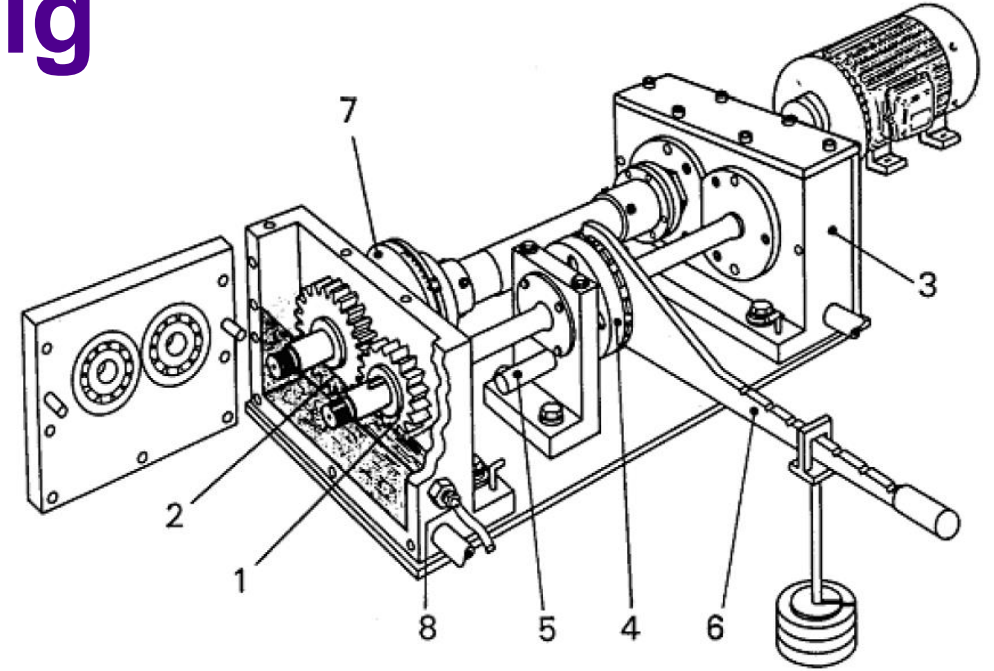
# FZG Gear test rig

## Test targets: testing gear contact and lubrication properties

- friction and power loss
- durability testing
- failure mechanisms, pitting, scuffing
- vibration and noise diagnostics
- on-line particle measurements

## Specifications:

- closed loop type rig
- loading torque 0 ... 1000 Nm
- rotating speed 0 ... 3000 rpm
- external lubrication unit with oil filtering and temperature, flow and pressure control





# Large scale gears tests

Large-scale, full power bevel gear test bench – 2 MW closed loop

Collaboration of ATA Gears and TAU Tribology and Machine Elements



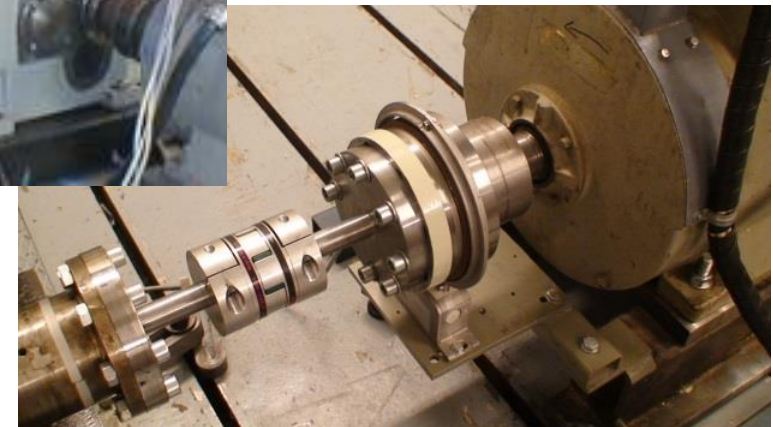
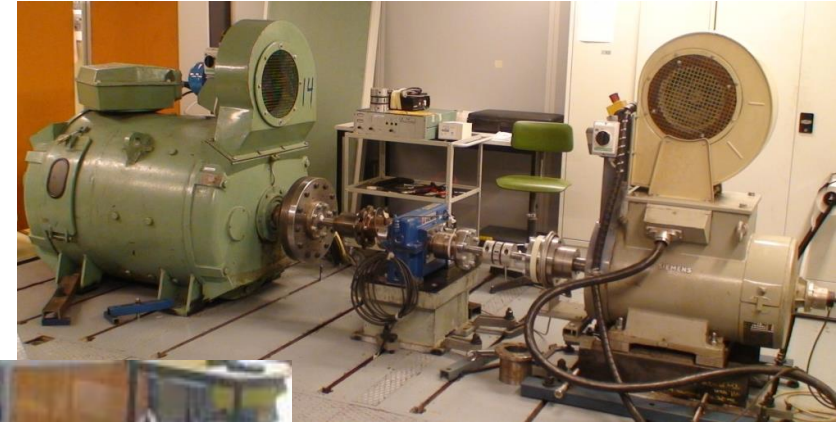
# Power transmission test rig

**Test targets: performance and durability tests of different power transmission components**

- lubrication condition
- failure mechanisms
- prototype testing
- vibration and noise diagnostics

**Specifications:**

- generator brake type rig
- isolated concrete foundation
- machine rail floor allows installation changes
- noise isolated test room
- max. power transmission 100 kW
- rotating speed 0 ... 2400 rpm



Versatile measurement possibilities



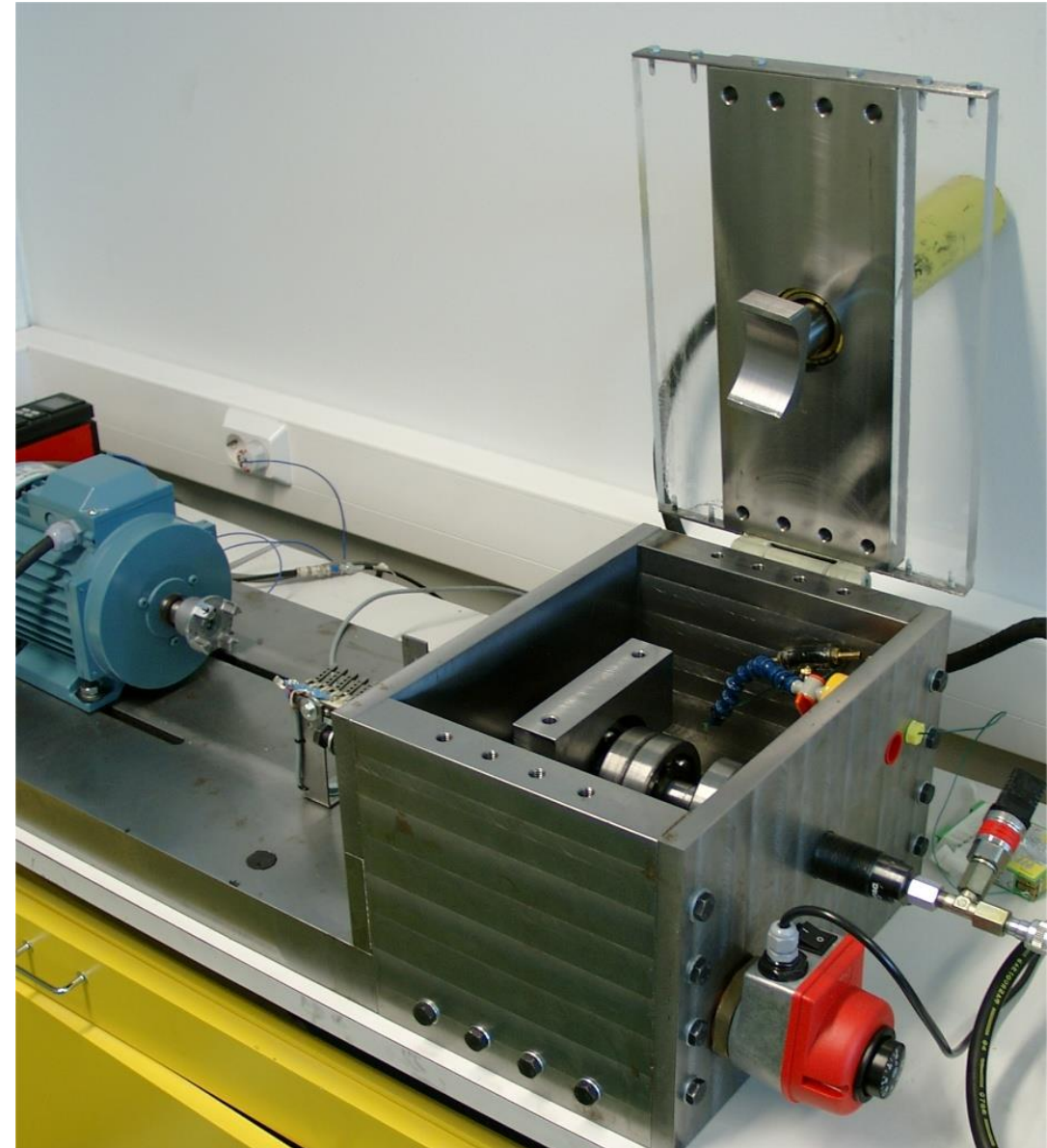
# Roller bearing test rig

## Test targets: evaluation of roller bearing performance

- friction and power loss
- lubricants, lubrication condition

## Specifications

- bearing outer diameter 90 mm
- normal and axial loading
- oil (bath) temperature control or
- external lubrication unit with oil filtering and temperature, flow and pressure control





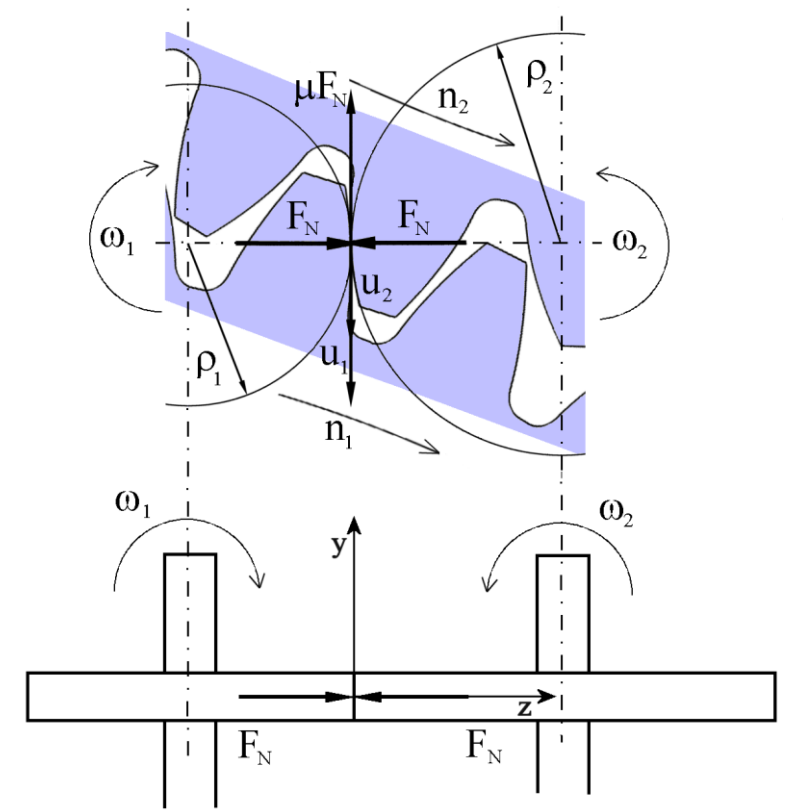
# Twin-Disc test rig

## Test targets: gear and rolling/sliding contact testing

- contact friction
- fatigue durability
- lubrication condition

## Specifications:

- adjustable elliptical rolling/sliding contact
- contact pressure 0 ... 3.0 GPa
- static and dynamic loading
- disc grinding transversal
- automated operation and sequence
- advanced instrumentation



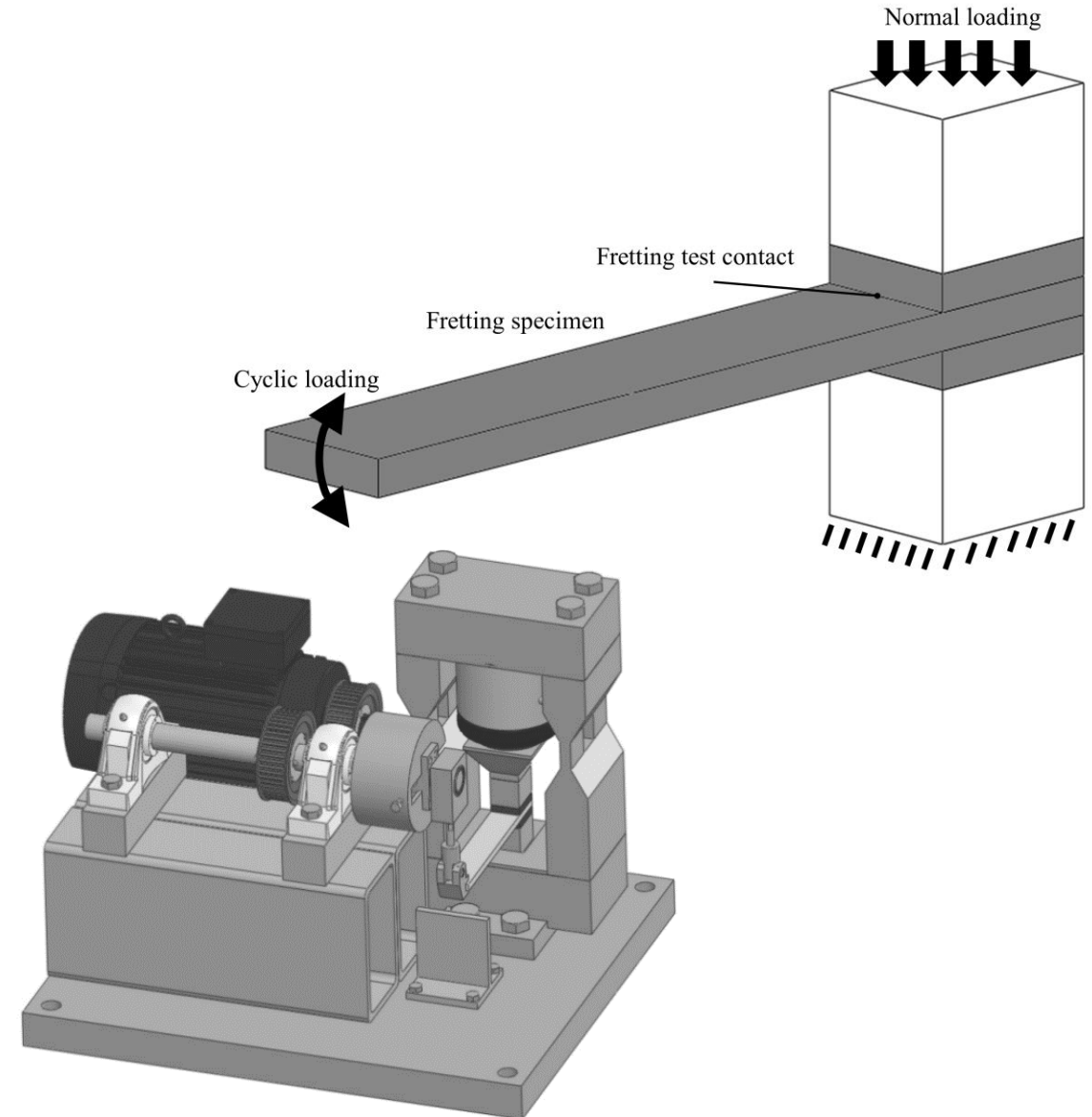
# Complete contact fretting test rig

**Test targets: fretting in complete contacts (i.e. 'sharp-ended' flat-on-flat type contacts)**

- fretting and plain fatigue S-N curves
- fretting wear

**Specifications:**

- large contact  $2000 \text{ mm}^2$
- loading frequency  $0 \dots 50 \text{ Hz}$
- nominal contact pressure  $0 \dots 200 \text{ MPa}$
- fully reversing or fluctuating bending loading
- automated operation (unoccupied testing)



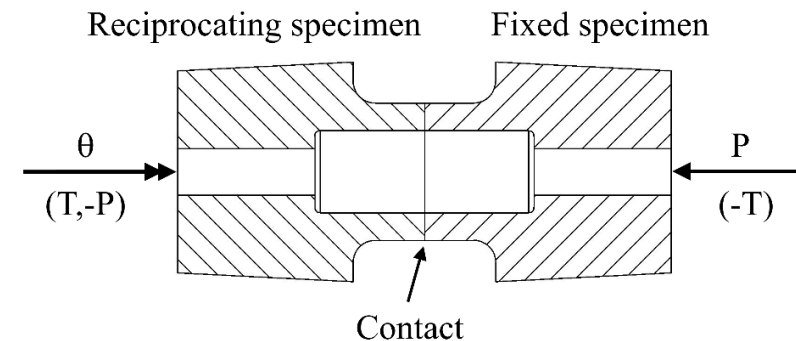
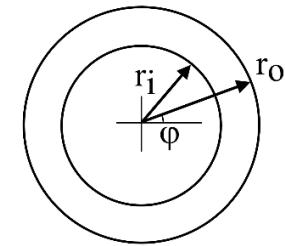
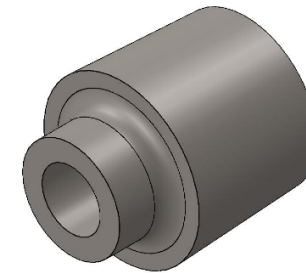
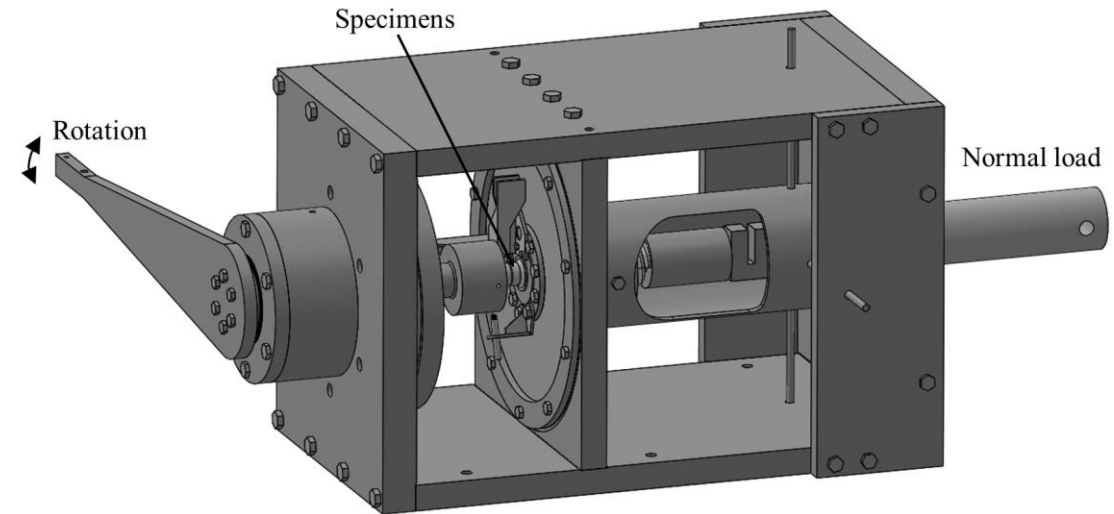
# Flat-on-flat fretting test rig

## Test targets: Fretting experimentation with annular flat-on-flat contact

- fretting induced friction
- fretting induced wear and cracking

## Specifications:

- large contact  $314 \text{ mm}^2$
- loading frequency: 40 Hz
- nominal contact pressure: 5...100 MPa
- tangential displacement amplitude: 5...60  $\mu\text{m}$
- automated operation





# Tribometer PCS-MTM2

- The mini traction machine (MTM) instrument is used to simulate the tribological contacts under lubricated and unlubricated conditions. Fully automated traction mapping under different rolling and sliding speeds is performed with different loads and temperatures. Additional features provide the anti-wear additive film growth measurement, simulation of soft contact, wear measurement and reciprocating friction.
- A normal test is performed by placing a small sample of fluid in the oil pot, and then running a test consisted of series of loads, speeds slide/roll ratios, temperatures and film thickness measurement intervals. These tests can be set by the user or by running the custom programs available on the instrument software.

- **Specifications:**

- Load 0 - 75 N
- Contact Pressure 0 - 1.25 GPa (standard specimens)  
Up to 3.1 GPa with alternative specimens
- Speeds -4 m/s to 4 m/s
- Temperature Range Ambient to 150°C (below ambient with oil cooler)



# Vibration Testing

- Vibration equipment for monitoring, diagnostics and testing
- Industrial and laboratory applications



- LMS system for machinery vibration and modal testing
- IMC data acquisition systems
- B&K and LDS shakers
- Versatile sensors for different purposes
- Strain gage equipment, wireless
- Acoustic emission vibration and sound equipment
- Versatile analysis software



# Contacts

## Wear testing

Staff Scientist Kati Valtonen

kati.valtonen@tuni.fi

+358 40 8490142

## Tribology and machine elements

Prof. Arto Lehtovaara

arto.lehtovaara@tuni.fi

+358 40 8254220

Dr. Juha Miettinen

juha.miettinen@tuni.fi

+358 40 5916044



# Tampere Wear Center

<https://research.tuni.fi/twc/>

<https://twitter.com/TampereWearCent>

