

The Role of Neutrons in the Industrial R&D Sector

Rainer Schneider

Outline

- 1) VDI/VDE-IT GmbH at the interface of economy, politics and science
- 2) The world of the „customer“:
Development of materials, products and processes
- 3) Successful application driven research using neutron and synchrotron radiation
- 4) The role of neutrons for industrial R&D
- 5) Marketing strategies



VDI/VDE Innovation + Technik GmbH

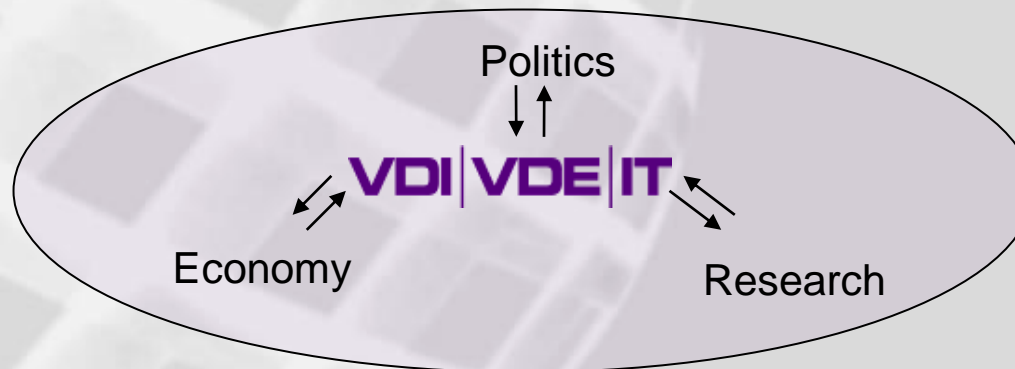
Success through High-Tech.

VDI/VDE-IT – Success through High-Tech.



Die VDI/VDE Innovation + Technik GmbH

- Since 1978 reliable partner of **economy, research/science and politics** in the high-tech area
- funding and coaching of **innovation processes at the interface between these**
- Is marked by an **interdisciplinary team** of more than 150 scientists and engineers



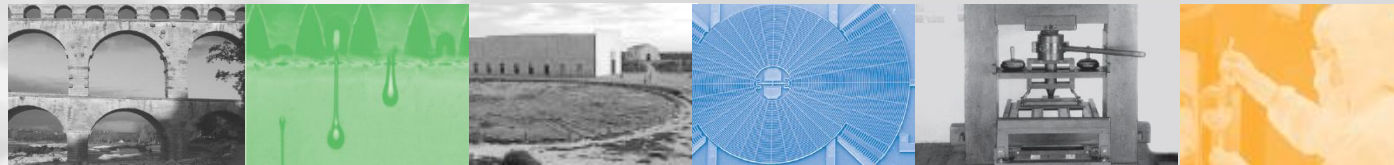
Portfolio

Covering the complete spectrum of innovation processes (research, validation, application)

R&D funding

Technology politics

Innovation management



Performance, Reliability and Verifiability

Design and Qualification of New Materials and Components



Rainer Schneider

Highly loaded industrial components

The „interest of the customer“

Task: „Guaranteeing a safe and effective operation“ through

a) Valid components modeling during the development process

b) Reliable quality control during the production process

c) Reliable maintenance tools and strategies

You have to be able to: **detect and classify defects**

You have to know: **the „Effects of Defects“**

In order to forecast **integrity of operation, remaining service life,
service strength**

Product life cycle

Product development

Choosing materials and geometries.
Construction, joining technologies
Aim: Maximum performance and
Maximum safety

Product manufacturing

Process monitoring
Quality Management and Control
Aim: effective production process
Max. and constant quality

Product in operation

Non-destructive Testing

Sensor principles
Structure-characteristics relationship
„Effects-of-Defects“
Defect classification and assessment
Qualification of testing tools

„Design for Testing“

Materials modeling
structure mechanics simulations

safe product operation

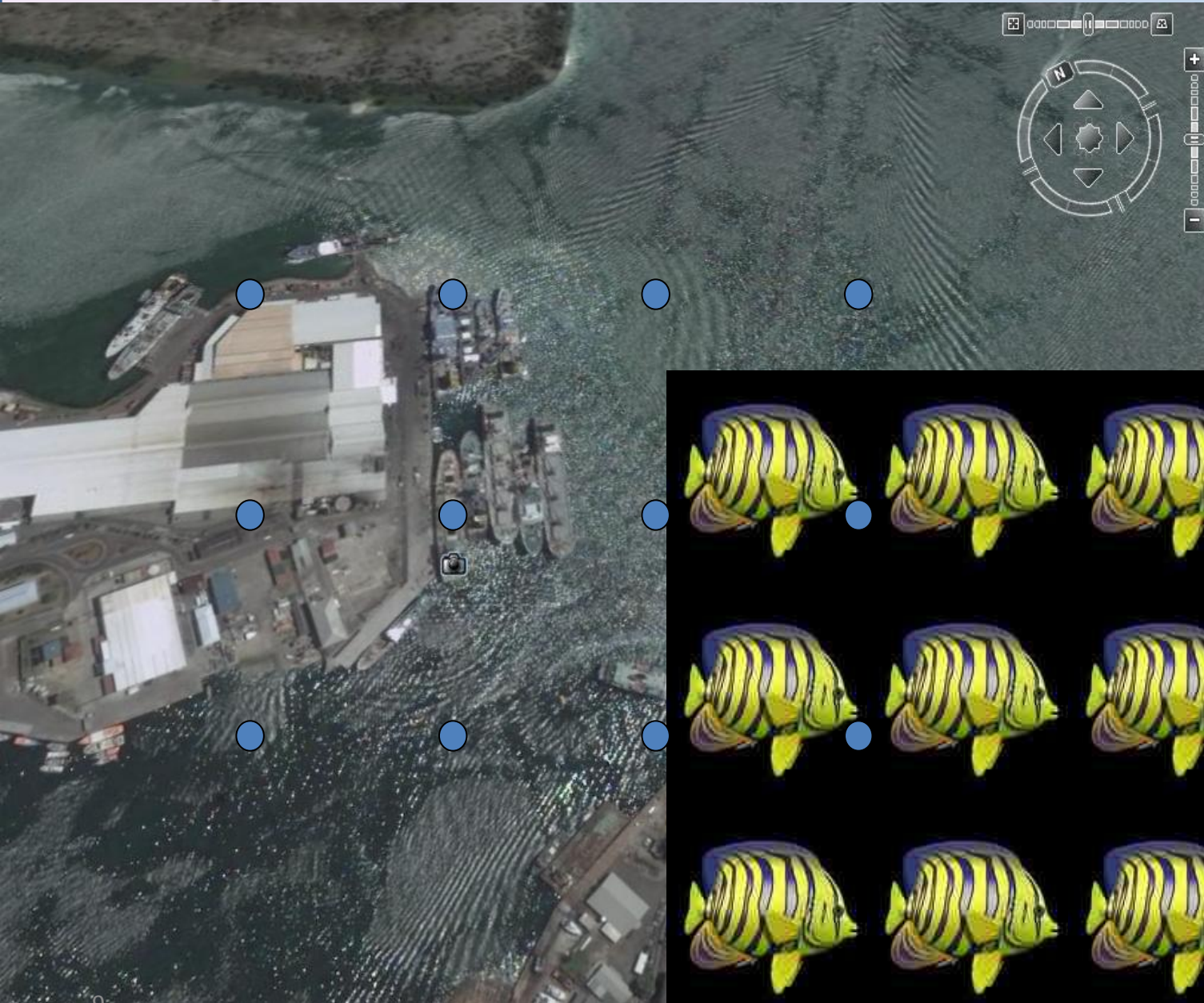
Product segregation

Choosing safe criteria,
but not too conservative

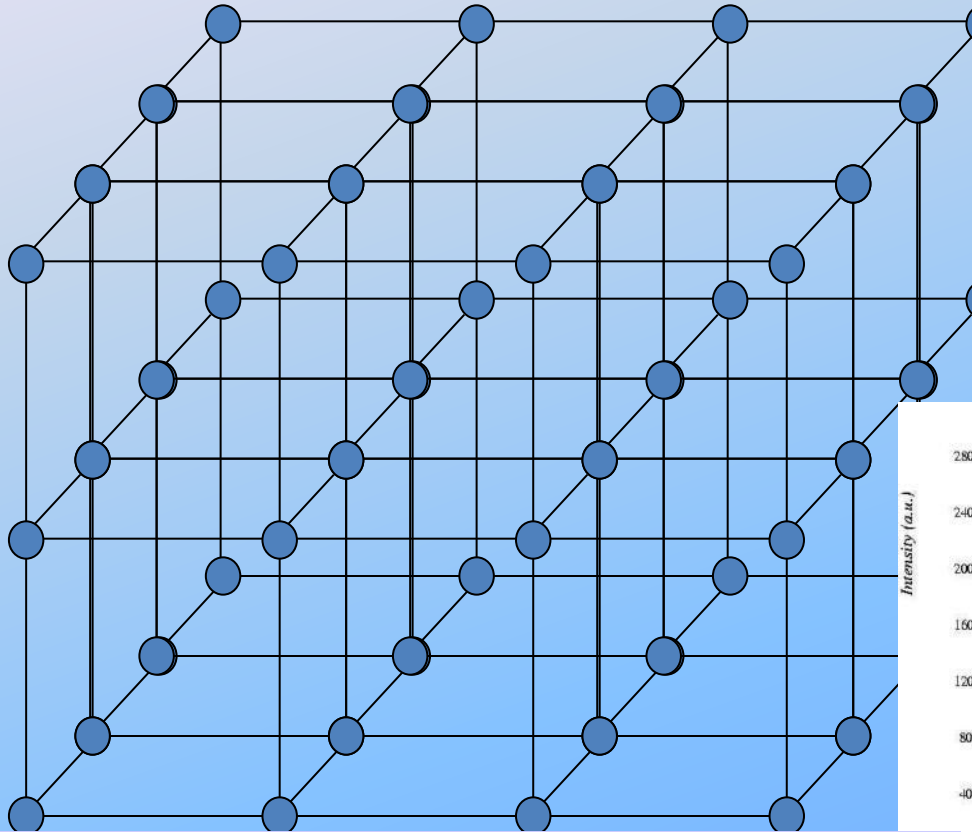
Quantitative reference
methods

Destructive testing

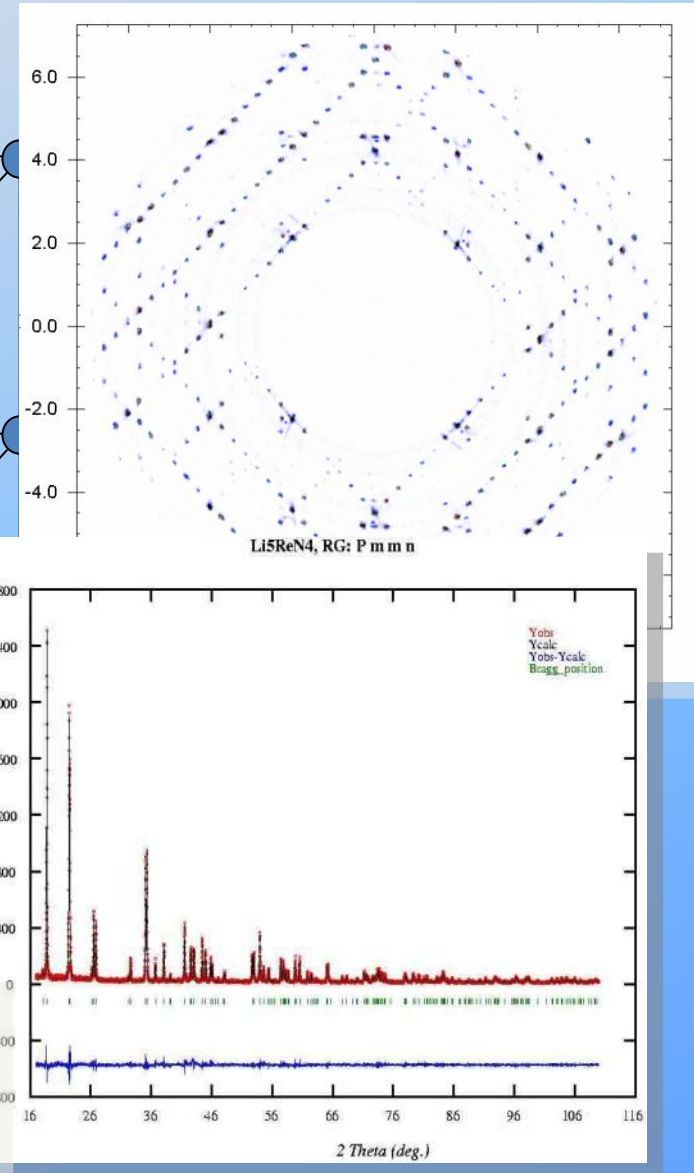
Wave phenomena – interferences, diffraction



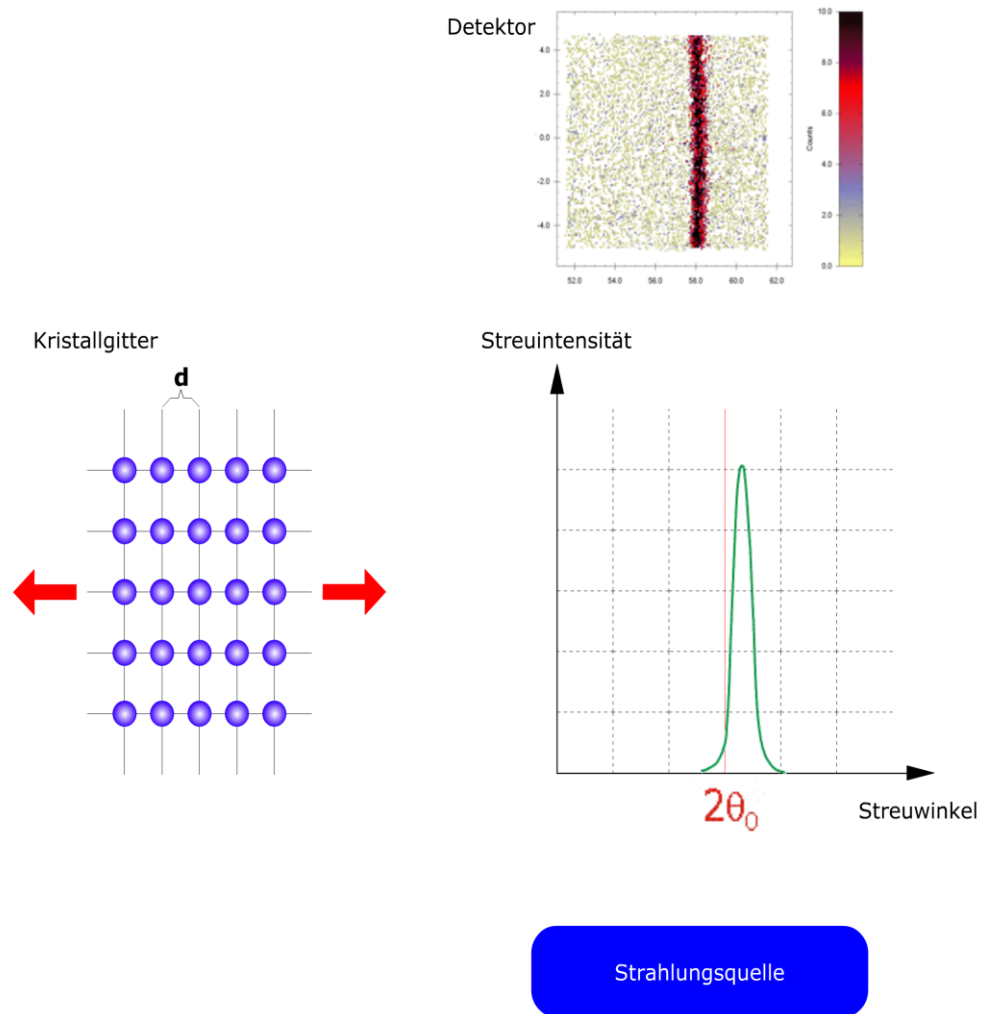
Wave phenomena – interferences, diffraction



Interference patterns of periodic crystalline structures allow the precise determination of the atomic order on atomic scale



Diffraction, residual stress analysis



Use of complementary radiations

Angular dispersive X-rays in laboratory

Two-axial stress states at the surface and within thin films

Synchrotron, white beam, energy dispersive or slits

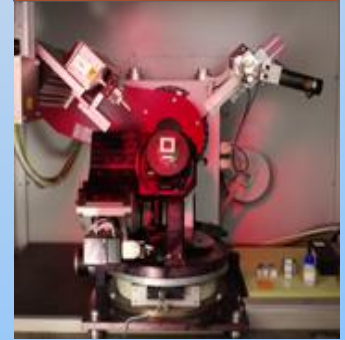
Residual stress profiles within the surface near region resulting from materials treatments like hardening, shot-peening, grinding, coating etc.

neutrons

Non-destructive evaluation of the three-axial strain tensor within the volume down to several cm below the component's surface

Eindringtiefe

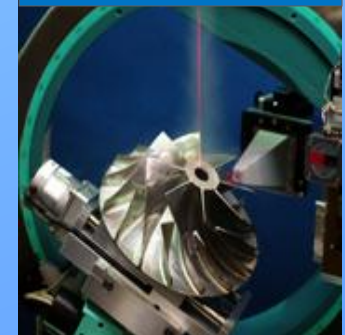
Röntgen < 10 μ m



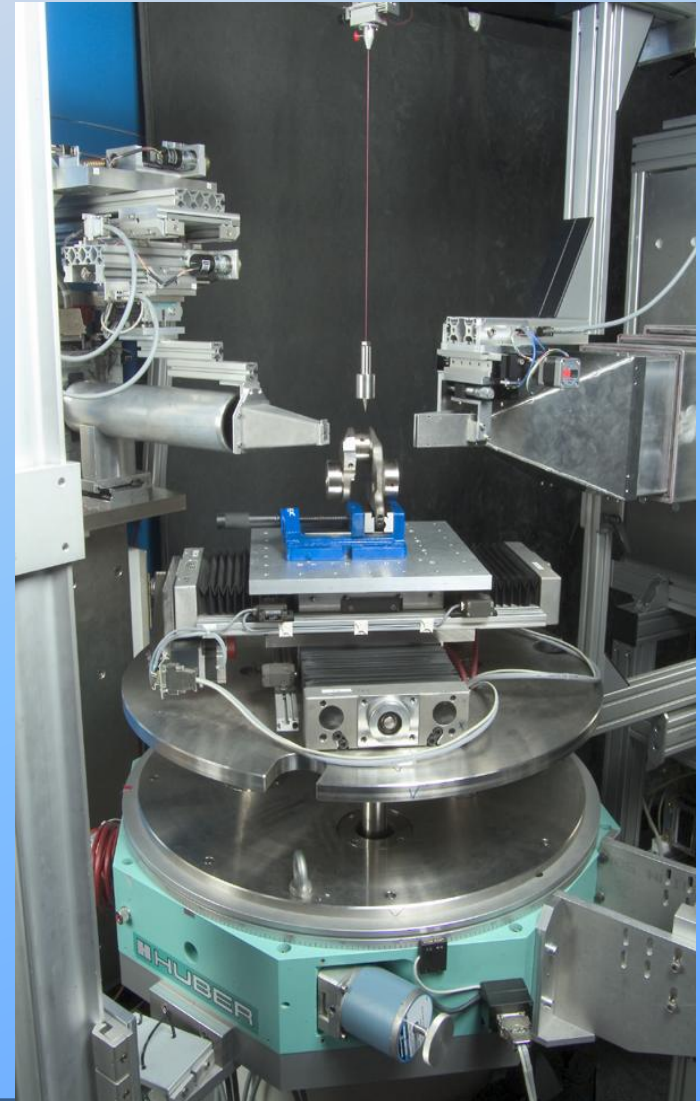
Synchrotron < 250 μ m



Neutronen bis zu 10 cm



Materials Research at FRM II: StressSpec



Materials Research at FRM II: StressSpec

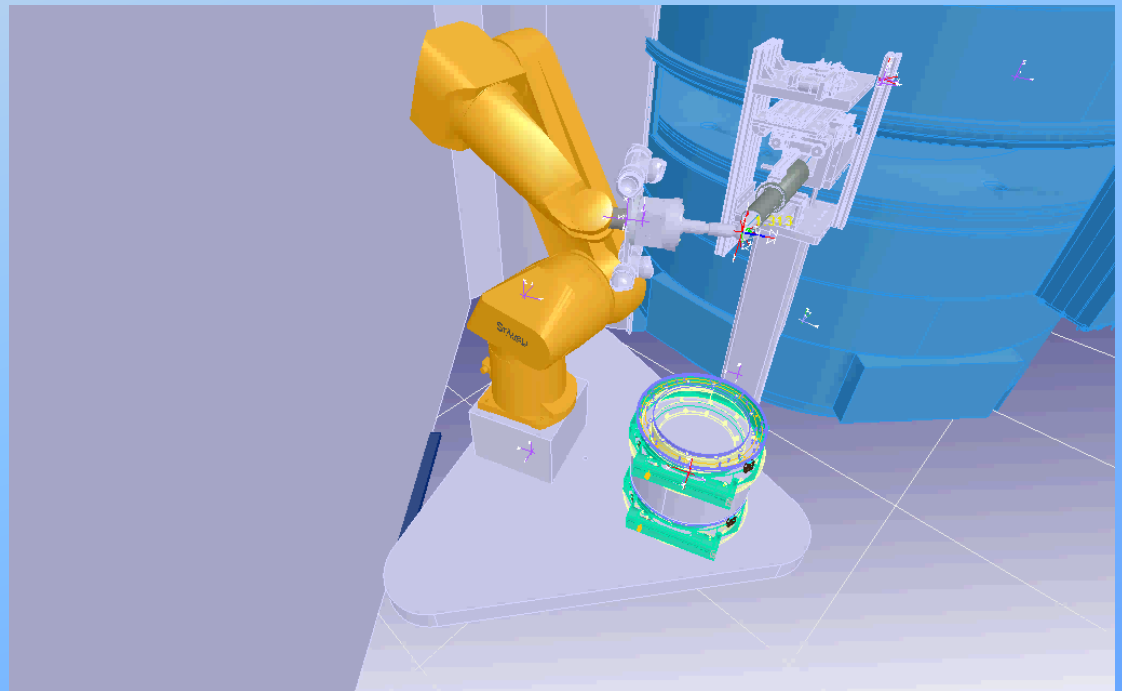
Instrument



- Roboter project (BMBF-Projekt: 03BR7CLA)
- Optimization Neutron Optics
- Detector

Science

- Improving surface scans
- Automated positioning
- Textur analysis

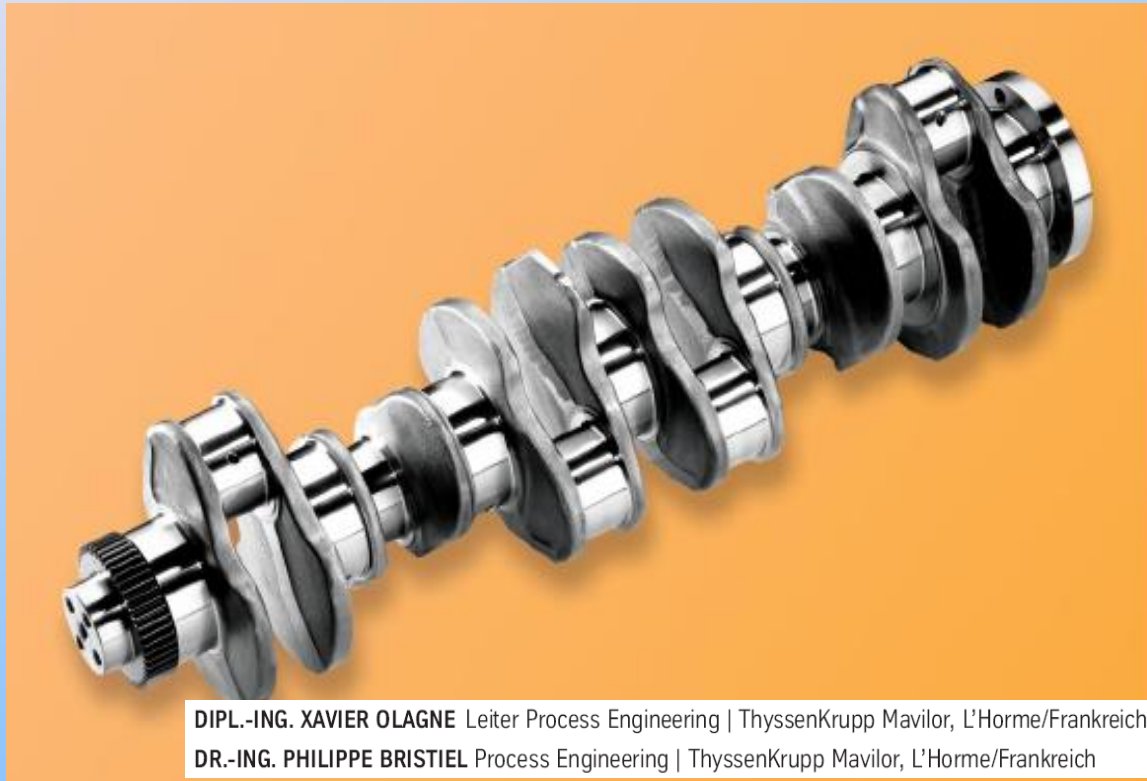


truck-crankshaft: neutrons and simulation

ThyssenKrupp

techforum

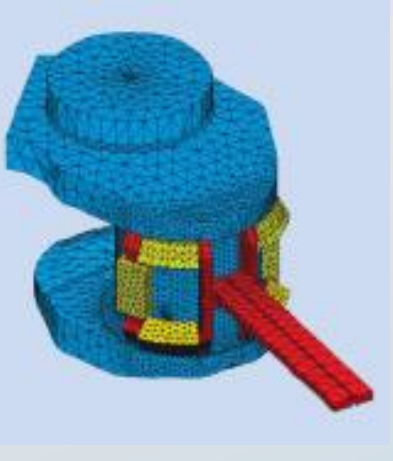
Juli 2003



aiming at:
endurance limit
efficiency, profitability

FE-simulation of the induction hardening process

FE-simulation of the hardening profile



induction hardening process:

- 1) heat treatment
- 2) quenching
- 3) annealing

process parameter:

inductor design

heating energy

-frequency

-duration

challenge: modelling

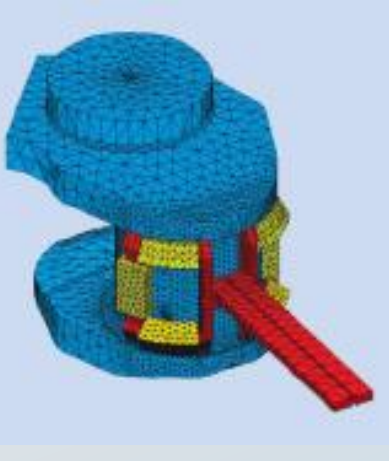
- complex 3d geometry

- coupled time- and temperature dependent materials characteristics
(electromagnetical, heat transfer characteristics, crystallographical, mechanical)

flow and temperature of
the quenching fluid

annealing temperature and
duration

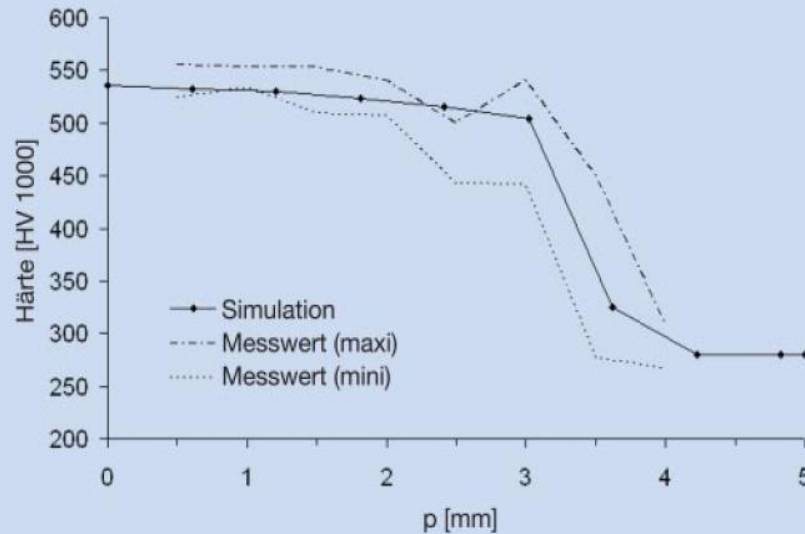
FE-simulation, hardening profile, axial stresses



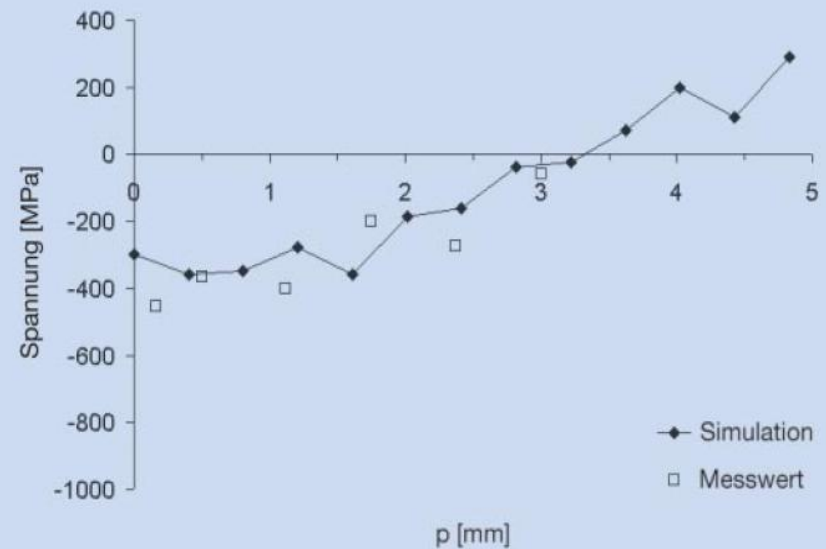
induction hardning process:

- 1) heat treatment
- 2) quenching
- 3) annealing

Härte-Tiefenprofil

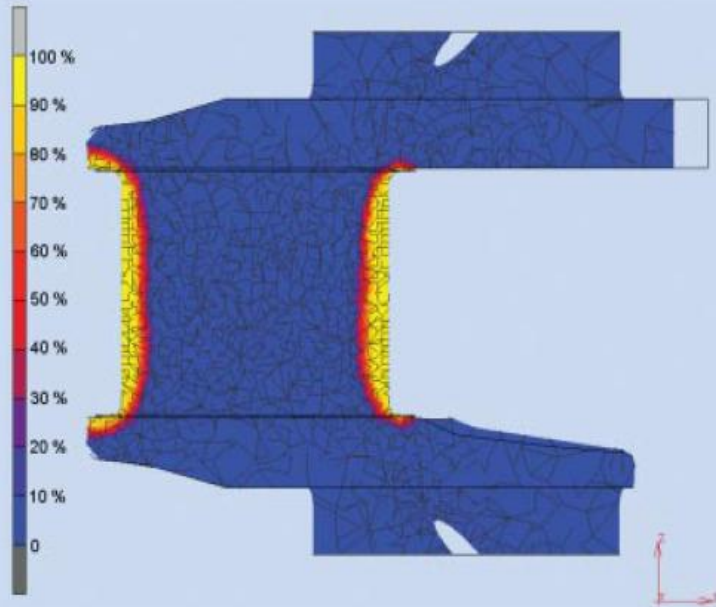


Tiefenprofil der Axialbeanspruchungen

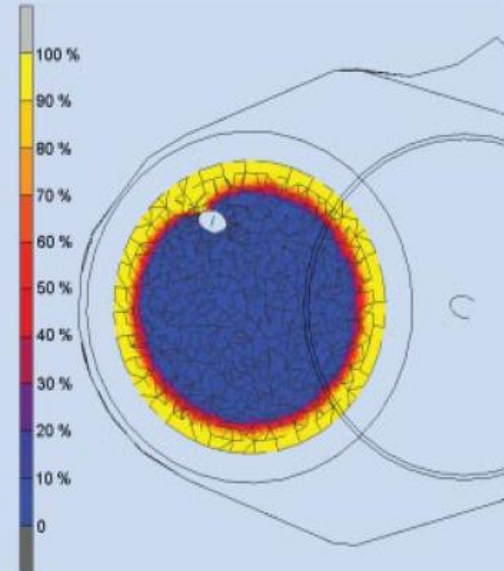


FE-simulation: martensitic phase distribution

Axialschnitt

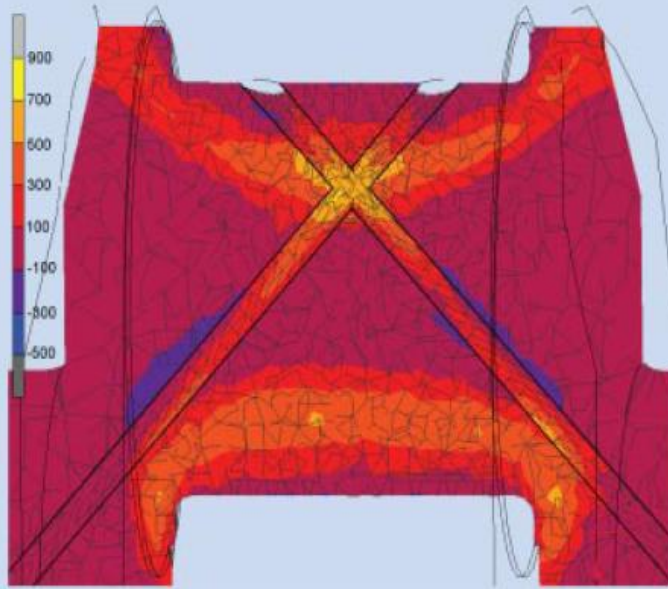


Querschnitt

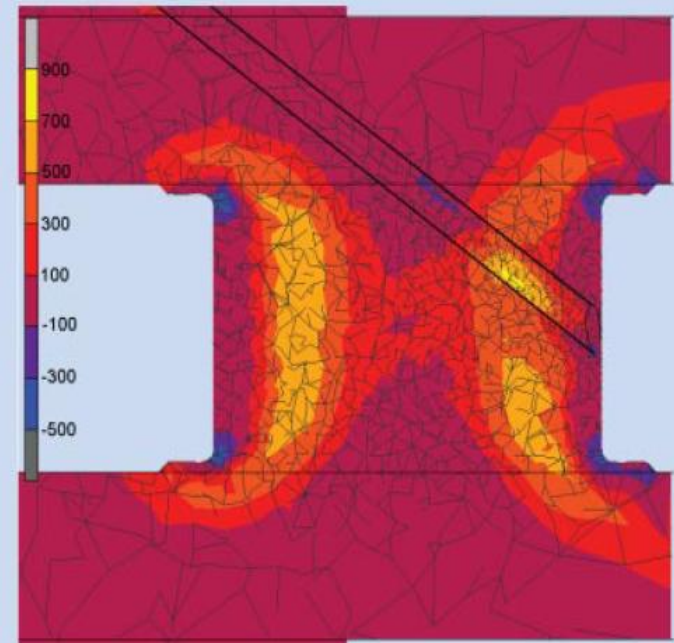
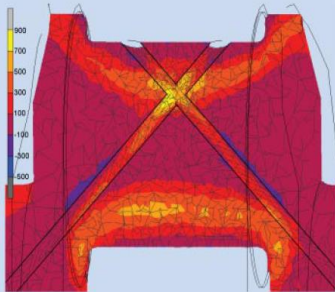


FE-simulation: residual stress profiles

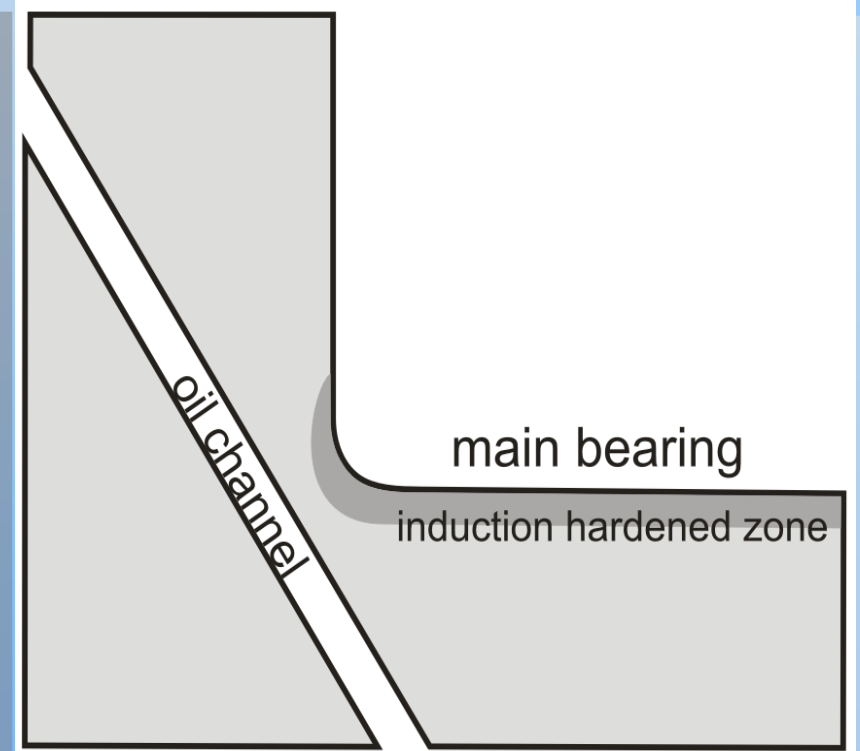
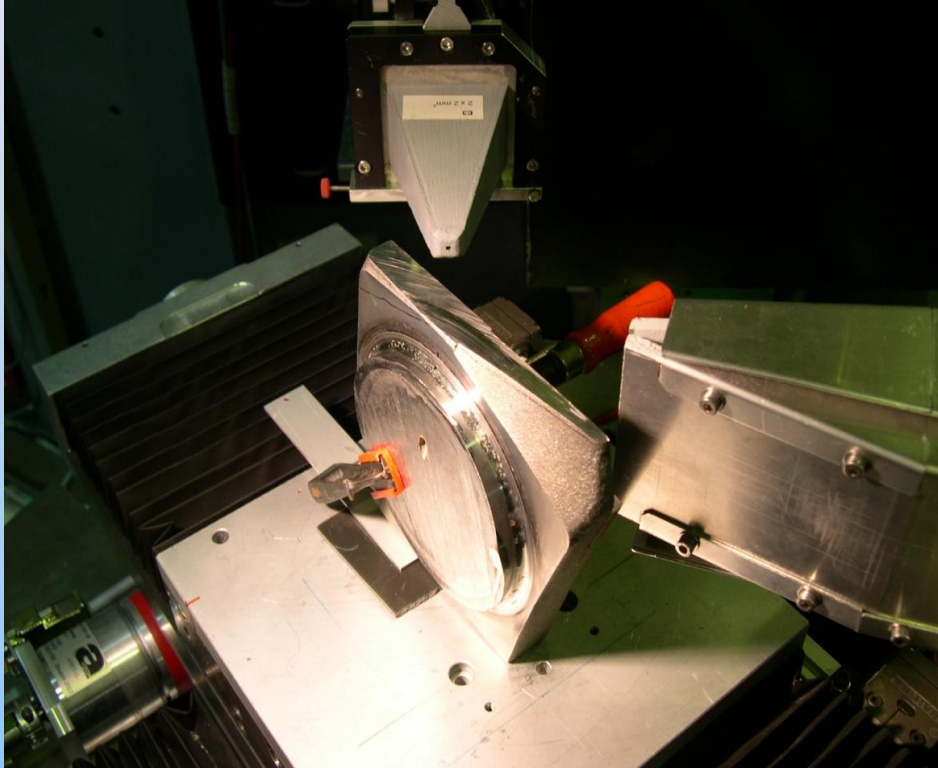
Eigenspannungen nach Härten und Anlassen



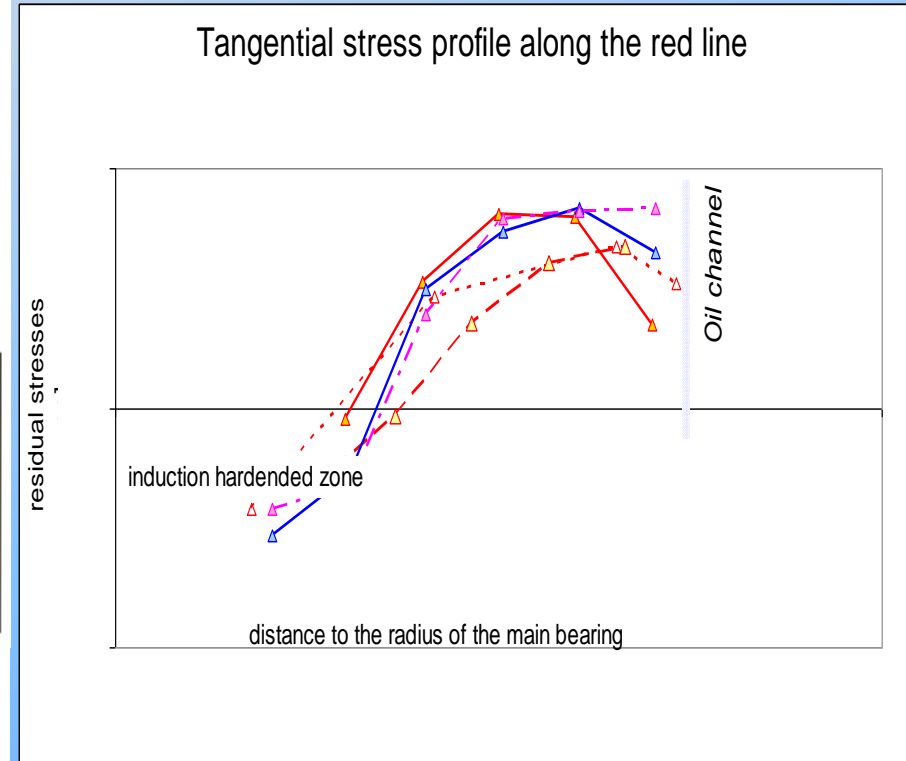
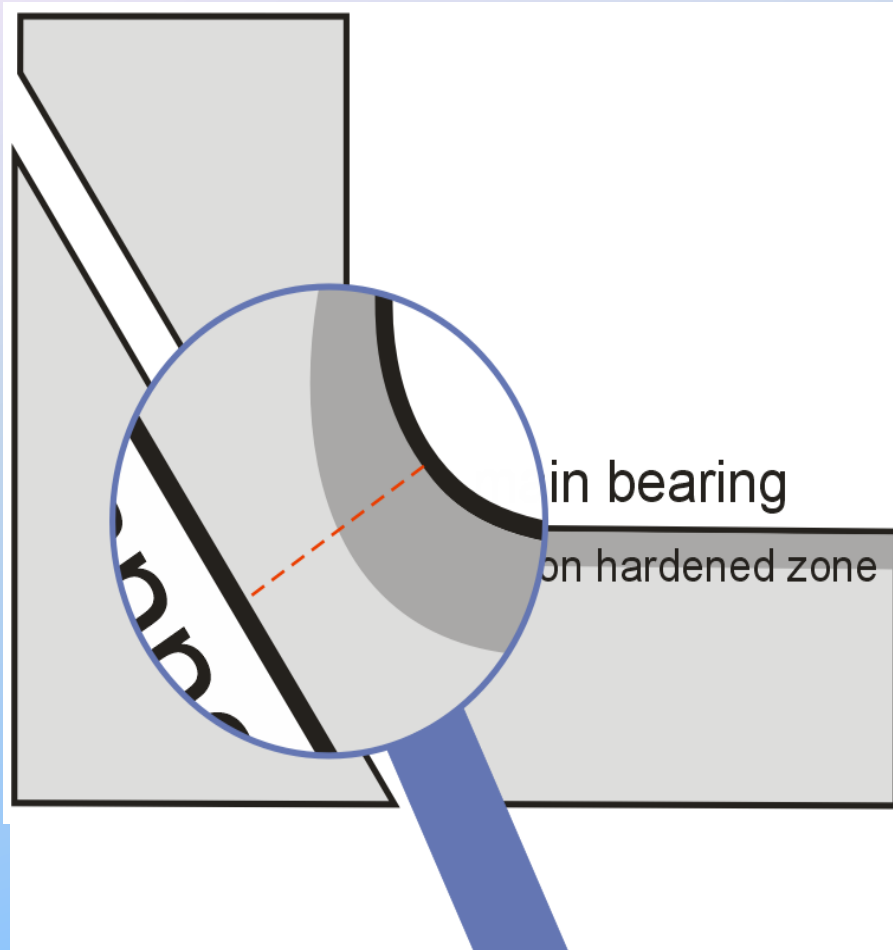
Eigenspannungen und Torsions-Betriebsbelastungen



neutron experiment: configuration

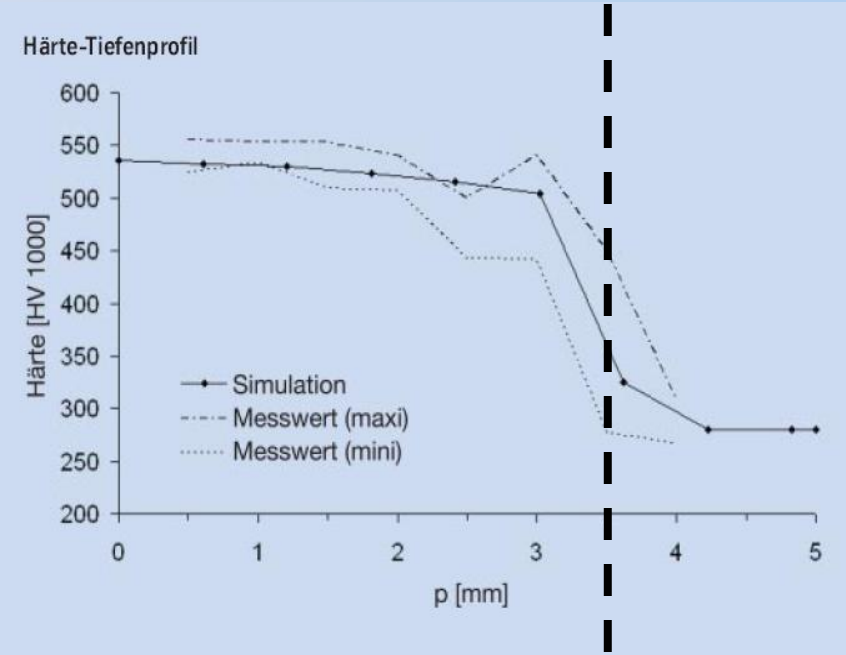
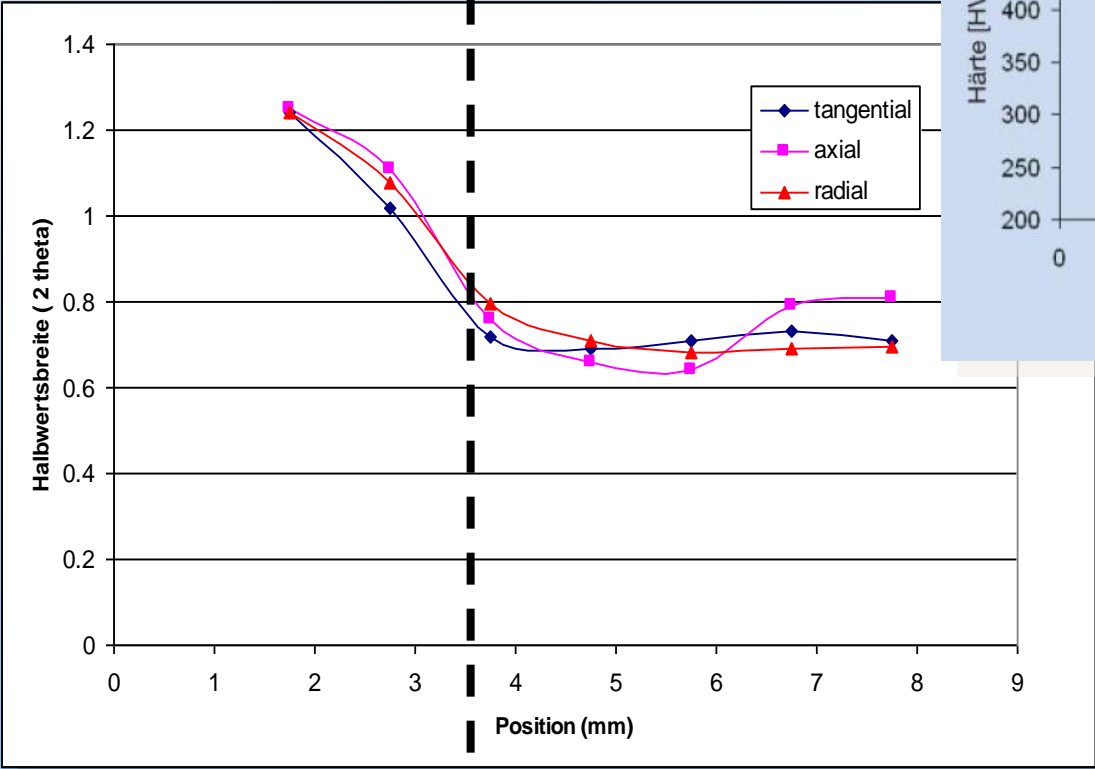


experiment, results



R. Wimpory, M. Hofmann, T. Poeste

peak width \sim martensitic distribution



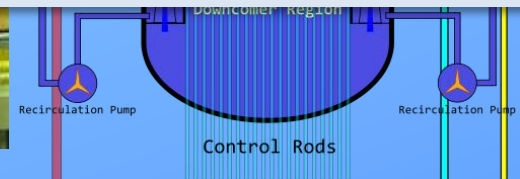
European Network NeT: Network on Neutron Techniques Standardization for Structural Integrity



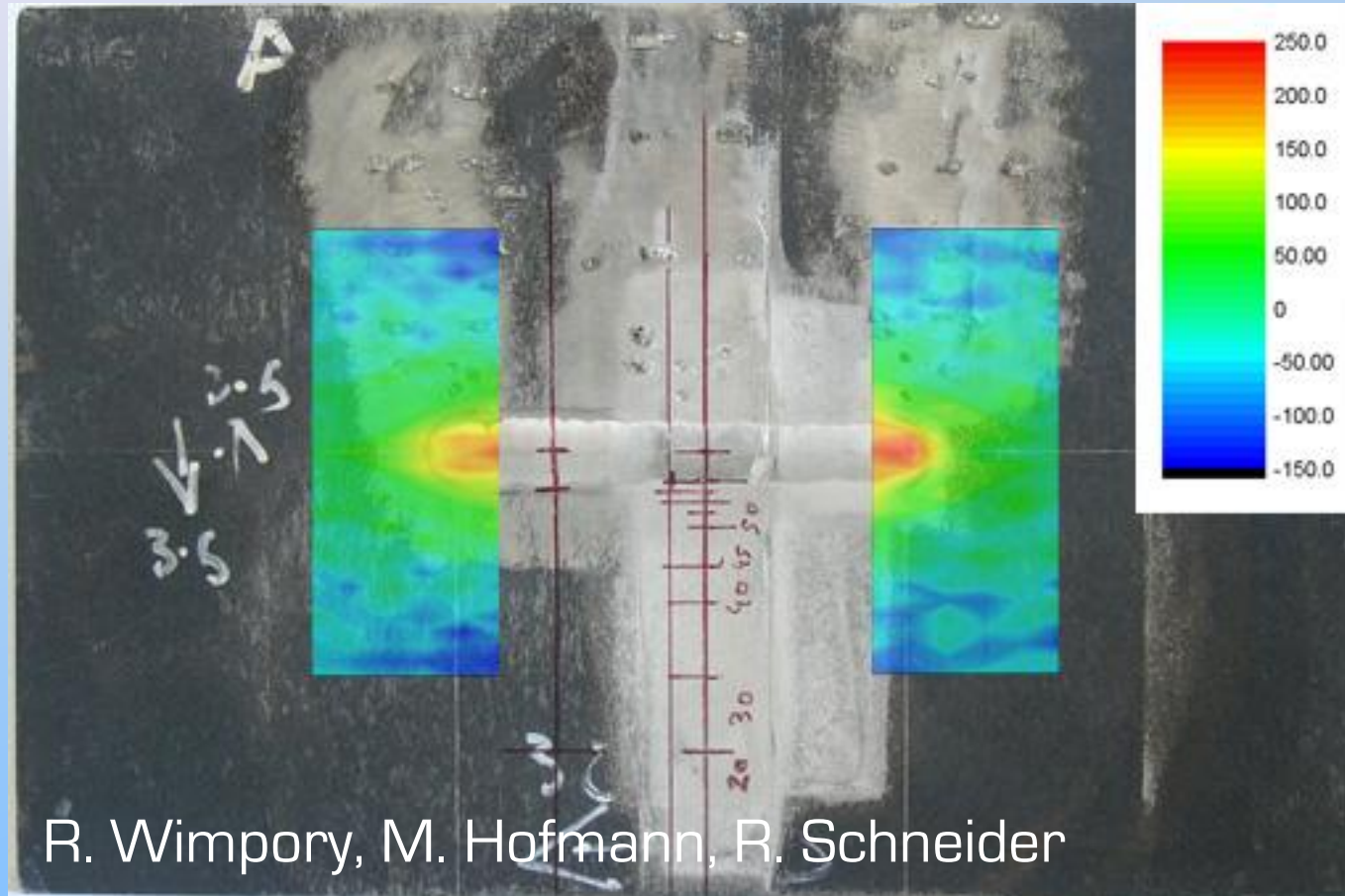
AEKI - Atomenergia Kutatóintézet - Atomic Energy Research Institute, HU. (Research Institute)

During the last two decades neutron methods have proven to be excellent means for advanced engineering applications and in particular in structural integrity assessment. However, the European industry is hampered from broadly using neutron research due to lack of harmonised and standardised testing methods. **The state of the art of assessing internal stresses, micro-structure and defects in welded nuclear components - as well as their evolution due to complex thermo-mechanical loads and irradiation exposure - needs to be improved before relevant structural integrity assessment code requirements can safely become less conservative.** This is valid for both experimental characterization techniques and predictive numerical algorithms. A concerted action by all actors toward further development and harmonisation of neutron methods (diffraction, small angle scattering, radiography) in relation to structural integrity assessment is undertaken within the new NET European Network

TUK - Technická Univerzita v Košiciach, SK, (University)
TUM/FRM II: Technische Universität München, DE, (University)
UB - University of Bristol, UK, (University)
UMAN - University of Manchester, UK, (University)
UP - University of Patras, GR, (University)
UWE - University of the West of England, UK, (University)
VUZ - Výskumný ústav zvaracský - Welding Research Institute, SK, (Research Institute)
WUT - Warsaw University of Technology, PL, (University)
YU - Yeditepe University, TR, (University)



Validation and Optimization of Materials Modelling for FE-Simulations



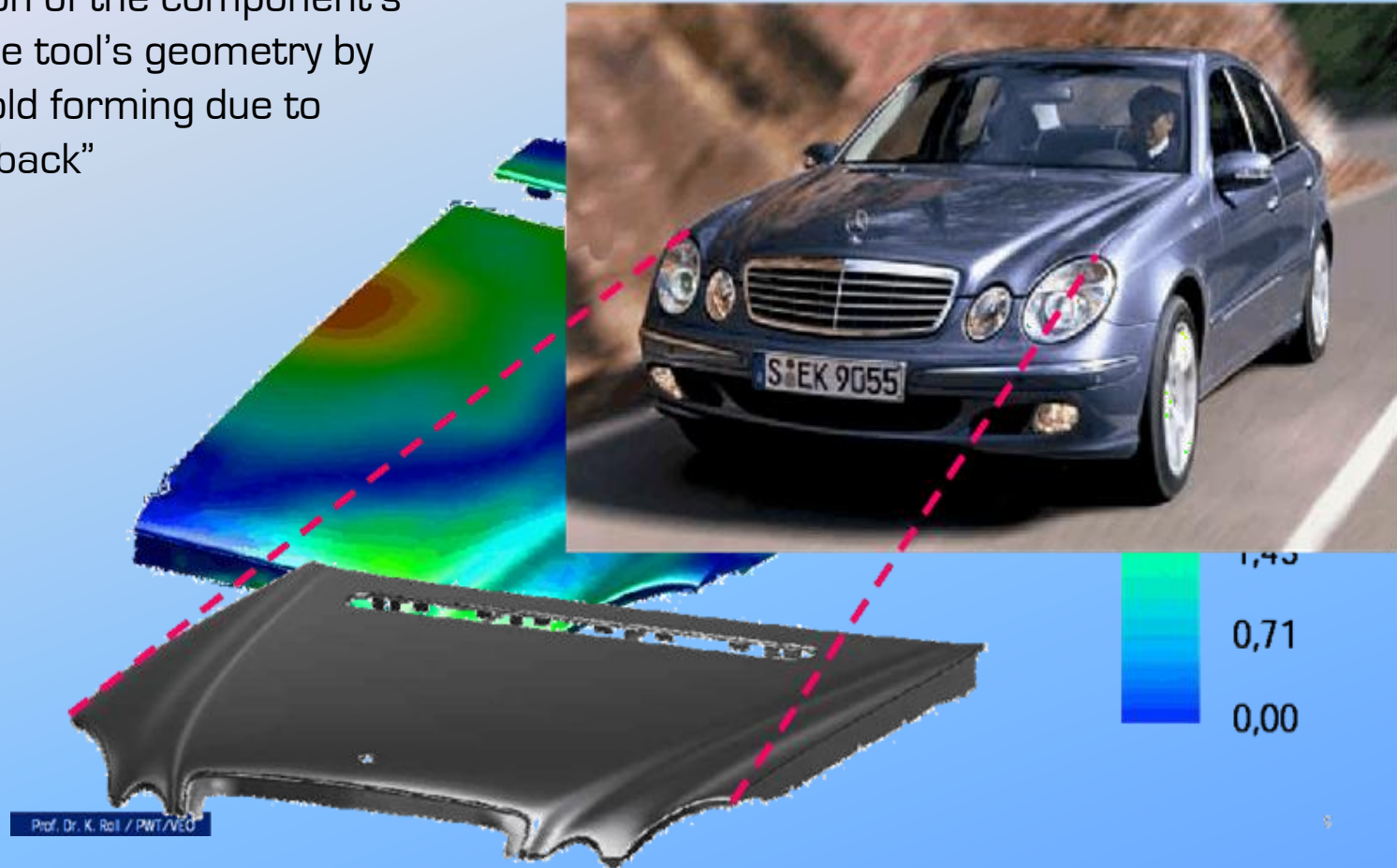
Longitudinal Stresses, 4mm below Surface
EU-Network NET

*Quality Check by neutron diffraction:
combustion chamber of the Ariane before
flight*



Springback-Effect

Deviation of the component's
from the tool's geometry by
after cold forming due to
"springback"



Herzlichen Dank an Prof. Dr. K. Roll / PWT/VED, Daimler AG

Understanding Materials as Basis for Development and Quality Assurance

- Verifiability needs understanding of fatigue behavior and destruction mechanisms
- Fatigue behavior of modern micro- and nanostructured composite materials is not yet understood quantitatively – still research needed
- Materials analytics tools at large scale facilities are marked by the potential to develop and optimize materials models describing operational and fatigue behavior through structure mechanical calculations

résumé

neutron and synchrotron methods are

- 1) **reference methods**
- 2) a **strong tool** for the **optimization of products- and processes** in combination with **simulation techniques** as well as **conventional ndt**
- 3) the use of neutrons has proven to be highly (cost-) **effective!**
- 4) **fast access through** facility-pooling

Experiences Interacting with Industry

networking of large scale facilities

a strong tool for the engineers!



Getting in Touch with Industry

- advertising material, flyers, web-pages etc. ...
- ads and articles in engineering magazines
presentations at engineering conferences and meetings (possible topics: hardening, cold forming, casting, forging, extruding), also: politicians, newspaper articles ...)
- long term activities with future impact: lectures at universities (of applied sciences)
- **hosting engineering committee meetings with possible interest overlap**
(AWT FA 13, FA25, VDI Beirat FRM II)
- industrials usually have already their forums and are driven by current problems and developments but usually not by general interest.
➡ NO general service workshop at the facility



Co-operations with industry: Two Types

Long-term scientific cooperations

- profitable for both parties
- often publishable
- slow access to the instruments
- low money flux per project < 100k€ p.a.
- in the case of high scientific interest, PhD student possible etc.
- possible methodical as well as scientific outcome

Short-term cooperations

- analytical assistance
- non-destructive reference data FE-Simulations or other experimental methods
- expert's report (as part of a failure analysis)
- fast access,
- usually confidential, no publication
- asking for certification
- high money flux (up to 50k€ per week)

Service for Industry: The Main Facts

- scientists should be involved in or in continuous contact to industrial committees (hosting meetings at the facilities)
- enabling fast and flexible access to neutrons
- increasing reliability and repeatability of the experiments
- standardization of procedures and tools
- establishing a self-stabilizing service system
(reinvestments, deficit guarantees by department)

VDI-W committee: non-destructive evaluation of materials and components



VDI-Gesellschaft
Werkstofftechnik



Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft



TECHNISCHE
UNIVERSITÄT
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Institut
Zerstörungsfreie
Prüfverfahren



BAM
Bundesanstalt für
Materialforschung
und -prüfung



in der HELMHOLTZ-GEMEINSCHAFT



HELMHOLTZ
ZENTRUM BERLIN
für Materialien und Energie



LKR

Ein Unternehmen der Austrian Research Centers



General Electric



VDI-W: Task Group „Tomography“

Aims:

- 1) demonstration of the **unique characteristics of different probes** (x-ray, synchrotron, neutrons) focusing on highly **promising new materials** (composites, casted light metals, hybrid materials)
- 2) development/definition of **standard samples** for calibration of tomography setups,
- 3) **harmonizing** data and protocol-**formats**, full documentation of measurement, reconstruction and image evaluation algorithms.
- 4) preparation of a **normative activities** for the tomography

Neutrons on the Market

- **ndt- and FEM- engineers** have their antennas at the market. They need neutron diffraction and imaging as reference for validation and calibration purposes. They **are the ideal „customers“**.
- large companies have their own ndt and FEM-teams. SMEs can only being addressed indirectly
- research reactors usually suffer from the public image being highly sophisticated and not of use for „every day life“
- research reactors are on the market since several decades. It is time now to discuss about the return of investment (ROI)!

Marketing Strategy

- Communication and presentations should be presented from the **engineering perspective**
- **Enabling fast access through facility pooling**
- The **methods available at large scale facilities** being of benefit for applied research (materials development, non-destructive testing, structure mechanics) should be **included with the curricula of engineering courses**.
- In order to setup a successful partnership with industry **scientists have to follow industrial quality assurance standards!**
- Close co-operation with engineering departments as well as institutes and companies especially dedicated to non-destructive testing and structure mechanical simulations

*Thanks a lot
for Your
Attention*