



Assessment of a steel bridge using magnetic methods

G. Seiler¹⁾, P. Kolakowski²⁾, P. Starke¹⁾,
C. Boller¹⁾ and J. Holnicki-Szulc³⁾

¹⁾ Chair of NDT and Quality Assurance (LZfPQ), Saarland University,
Saarbrücken/Germany

²⁾ Adaptronica z.o.o sp, Lominaki/Poland

³⁾ IPPT, Polish Academy of Science, Warsaw/Poland



Ageing Bridges and Related Issues



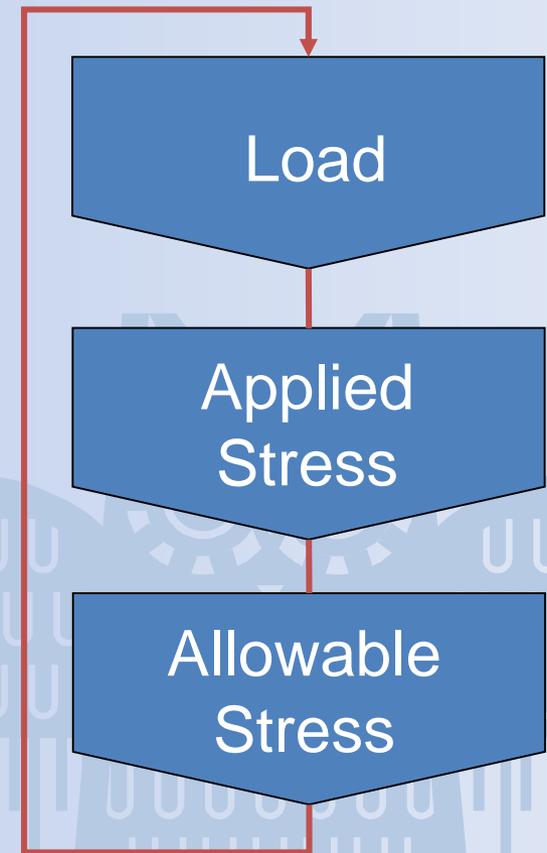
- Railway steel bridges in Europe are > 80 years old in average; oldest German bridge 175 years
- Operational conditions changed
- Environmental conditions changed
- Standards changed
- No adequate material data available
- Damage degree only observed visually with respect to corrosion
- Enhanced inspection effort required

Photos: www.dieolsenban.de
www.fotocommunity.de .



Key Elements in Structural Design

- Load (assumed)
 - Static Load: Ultimate Load
 - Fatigue Load:
 - Constant Amplitude Load
 - Random Load (Service Load)
- Geometry (given)
 - Notches
 - Stress States/Multiaxial Loading
- Material (to be selected)
 - Strength
 - Ductility



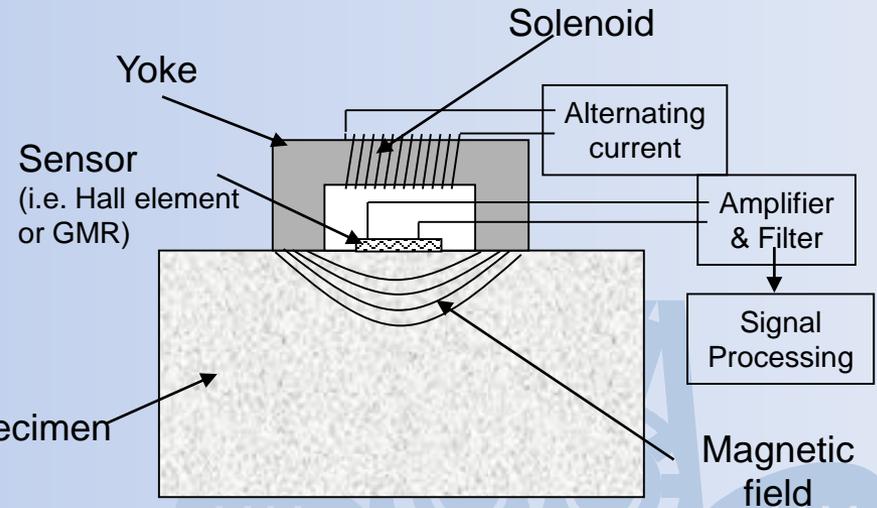
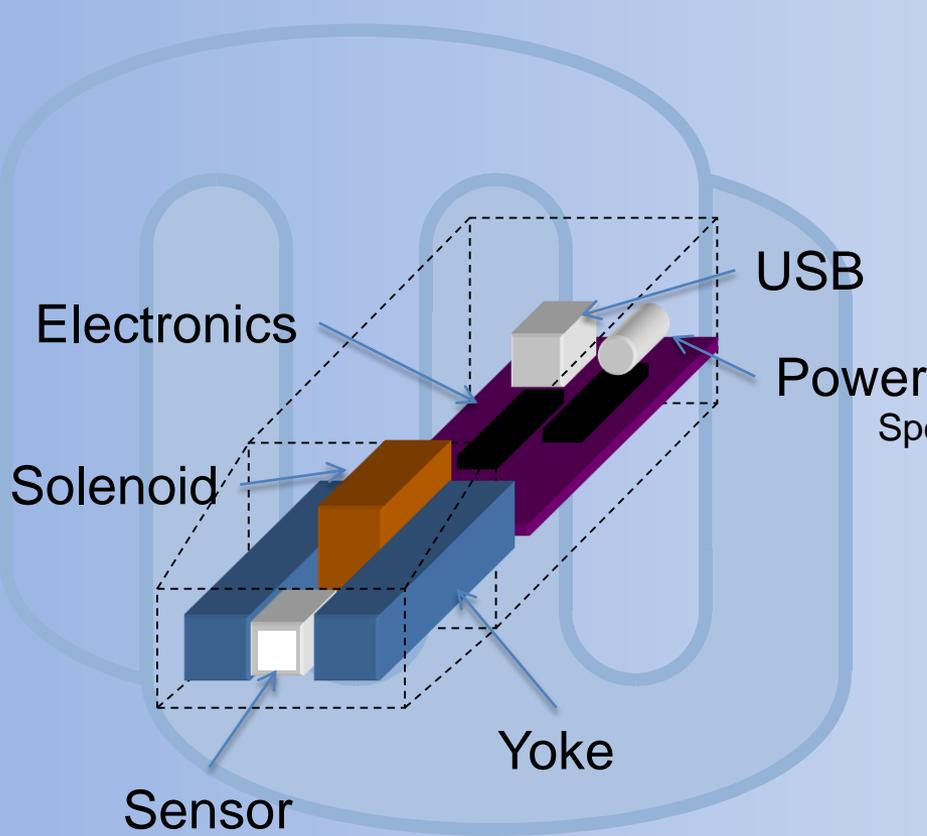
Allowable Stress

>

Applied Stress ?



MicroMach Monitoring Device

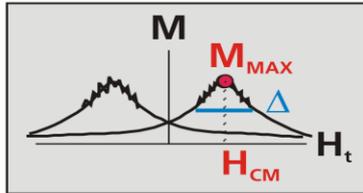


Figures left & bottom: Fraunhofer IZFP

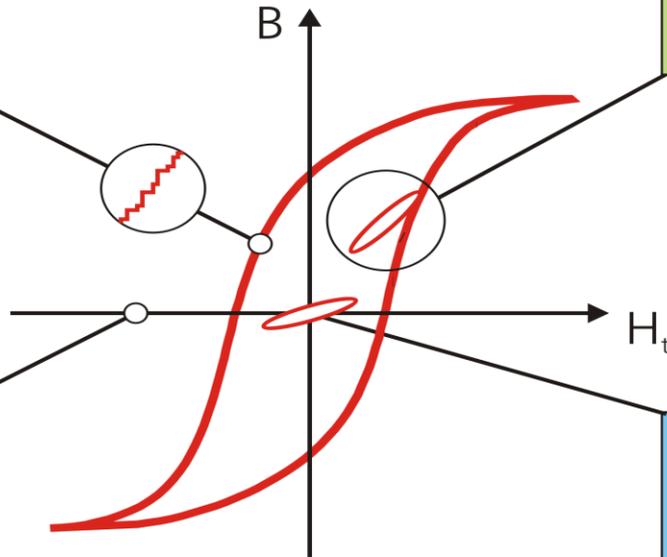


Electromagnetic Techniques and their Potential for Data Fusion (3MA Approach)

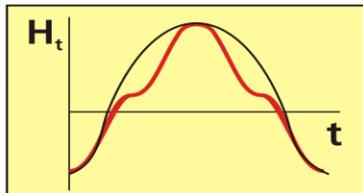
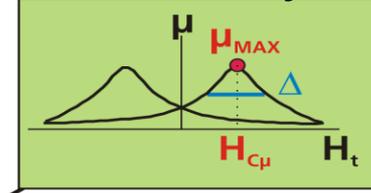
Barkhausen Noise



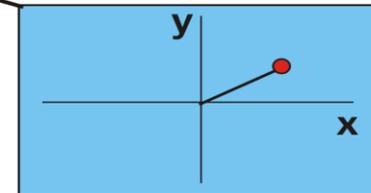
Magnetic Hysteresis Curve



Incremental Permeability



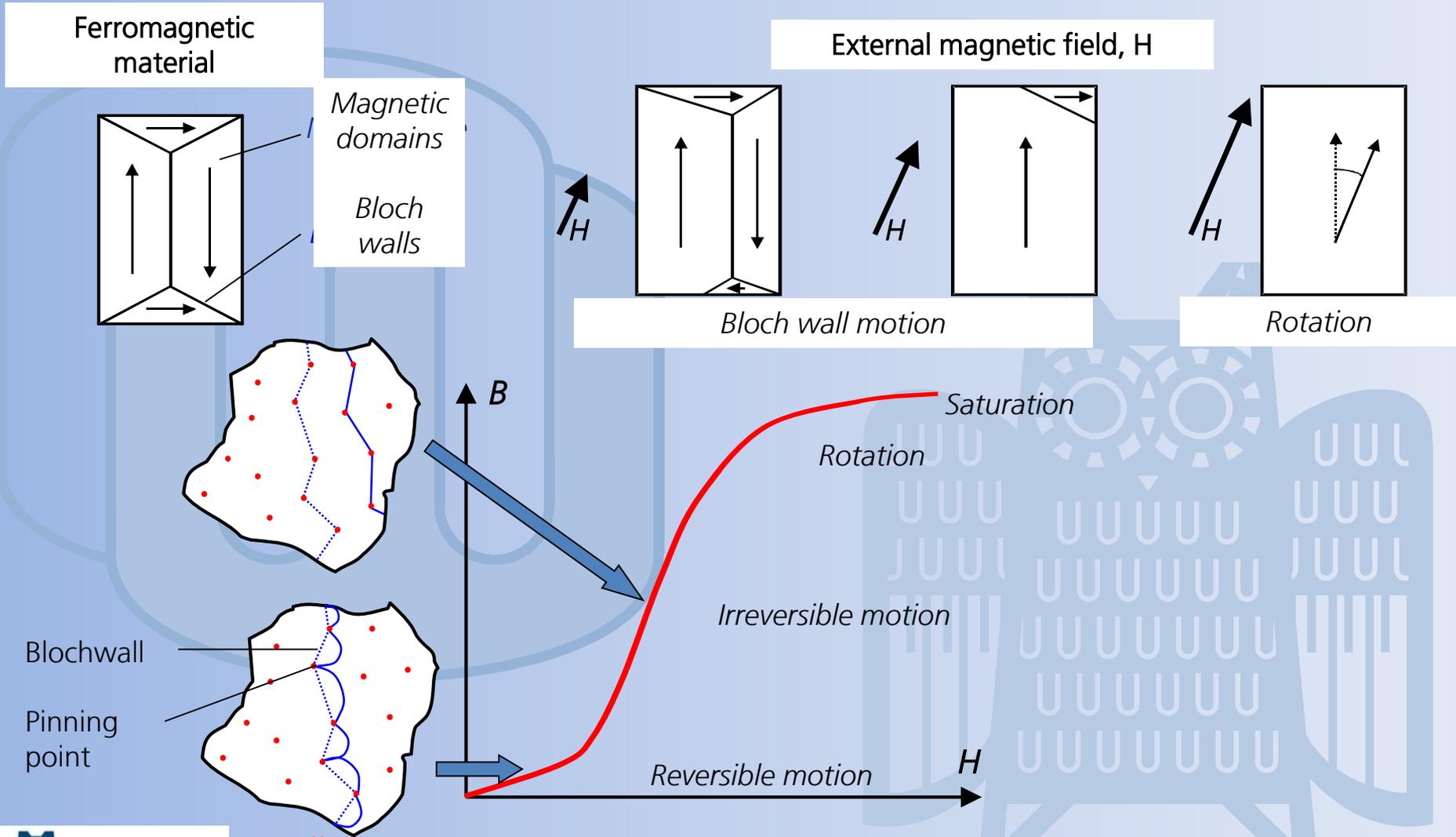
Distortion of Tangential Magnetic Field Strength



Eddy Current Impedance

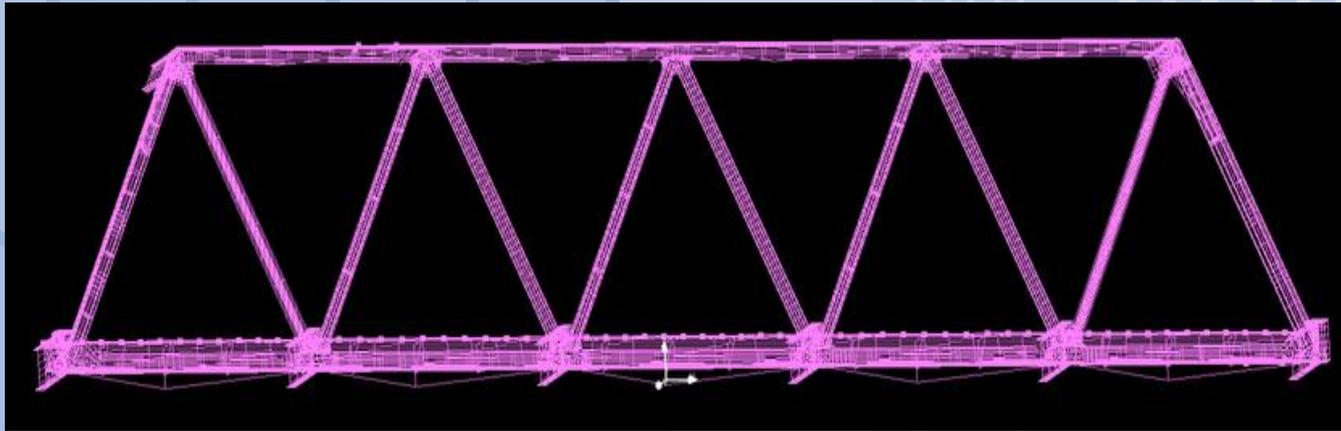


Magnetisation in Ferromagnetic Materials



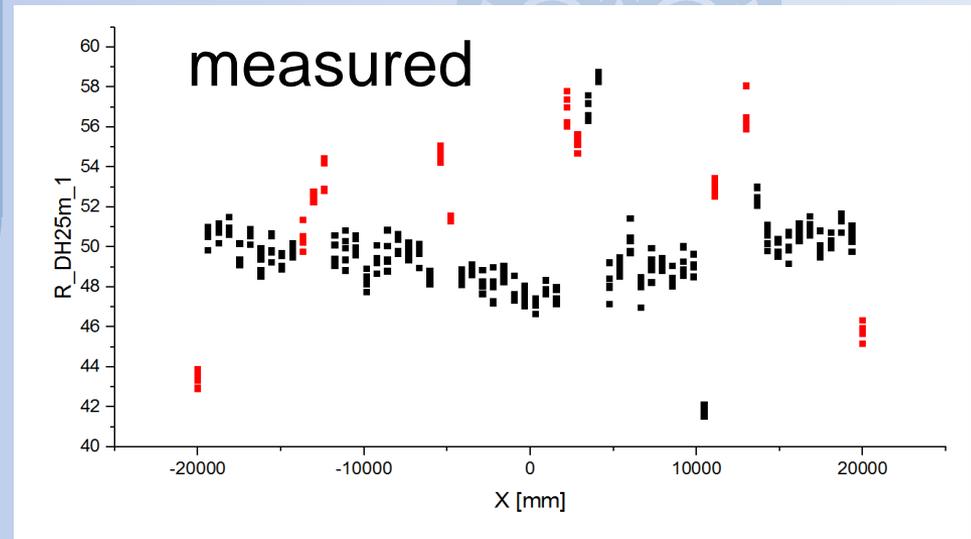
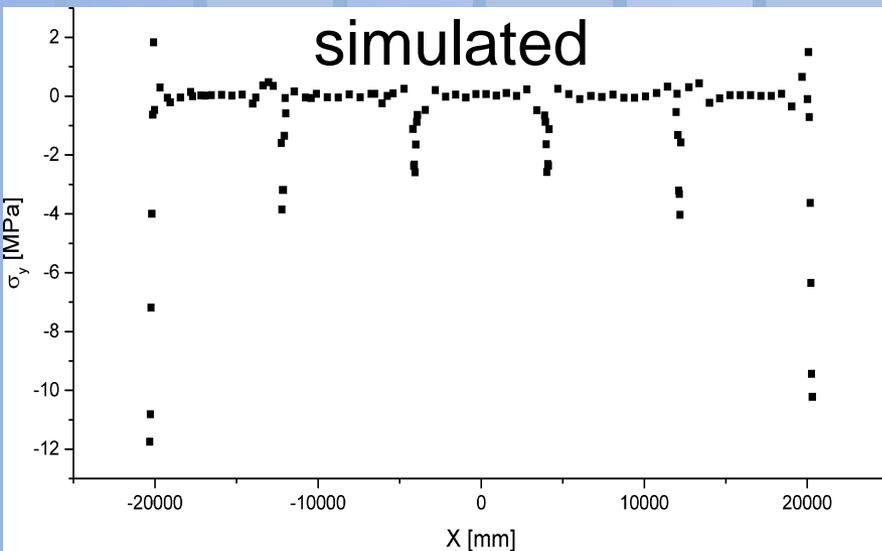
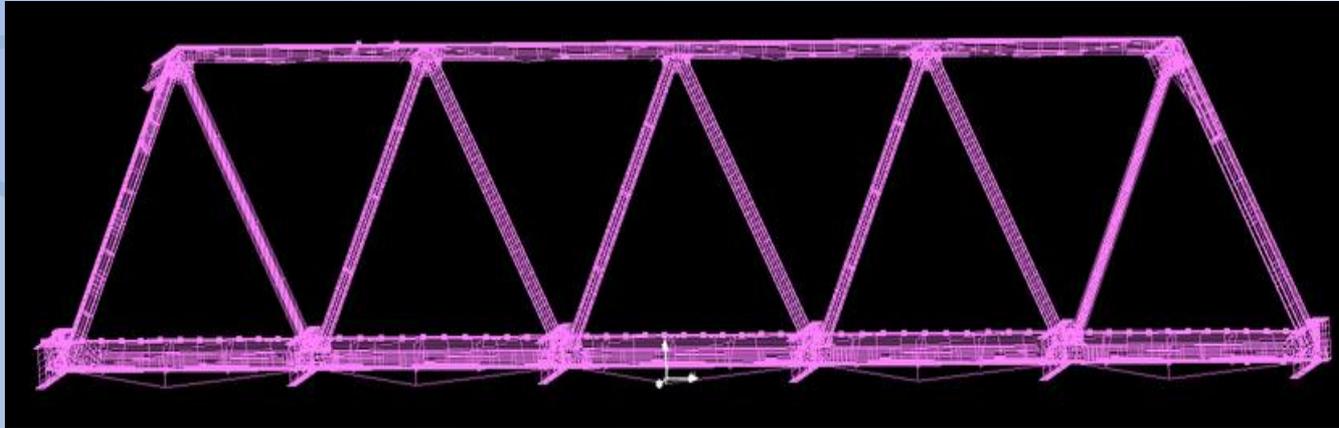


Steel Railway Bridge to be Inspected



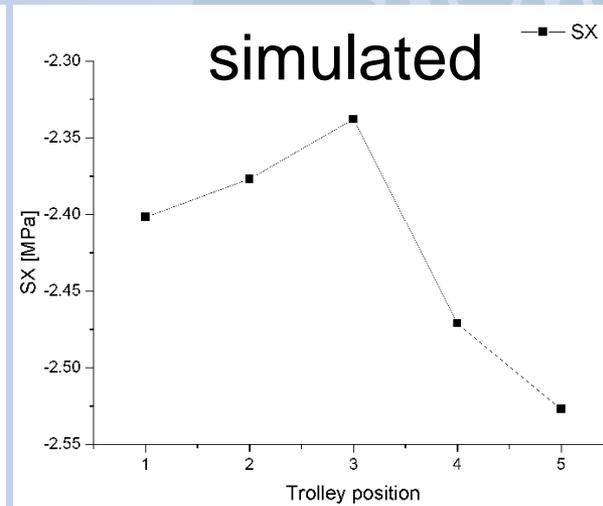
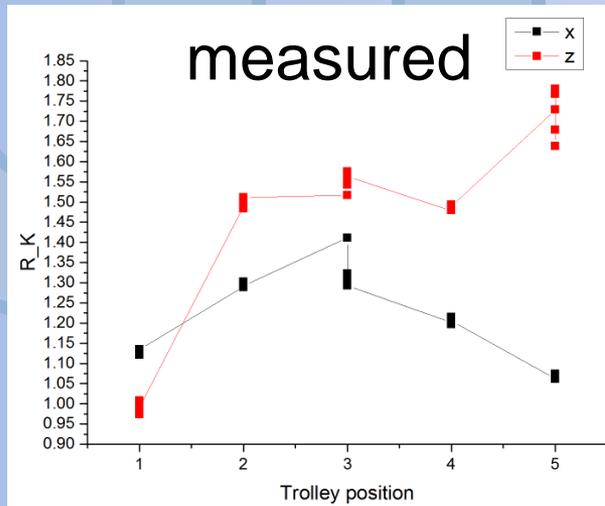
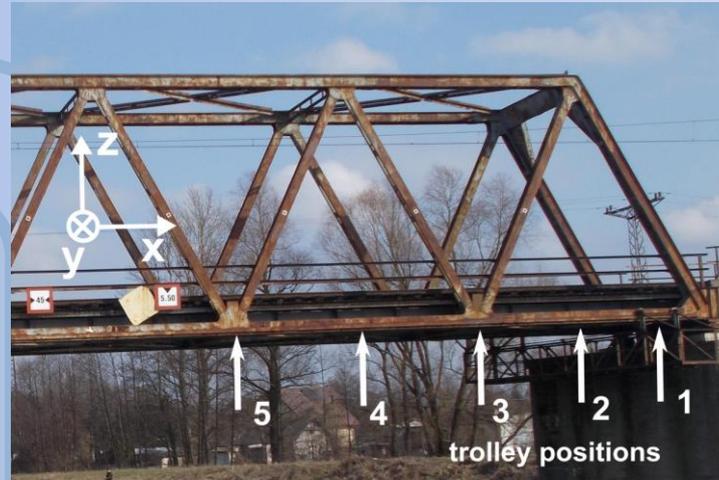


Stress Distributions along Lower Girder Beam





Measured and Simulated Stress Data for Different Loading Conditions



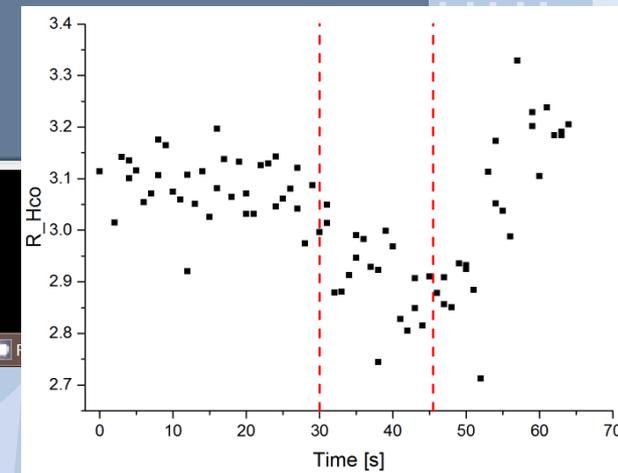
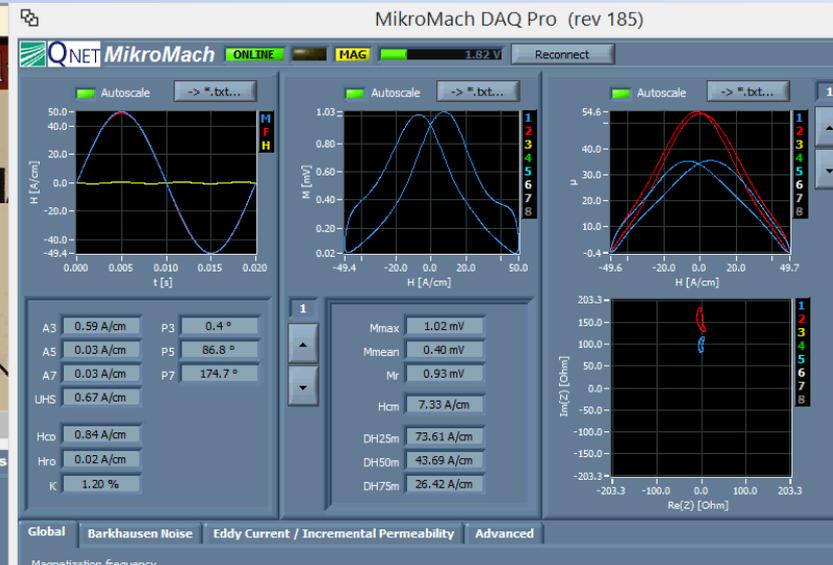


Monitoring of Train Crossing over Bridge

The screenshot displays a Windows desktop environment with several open applications:

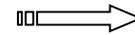
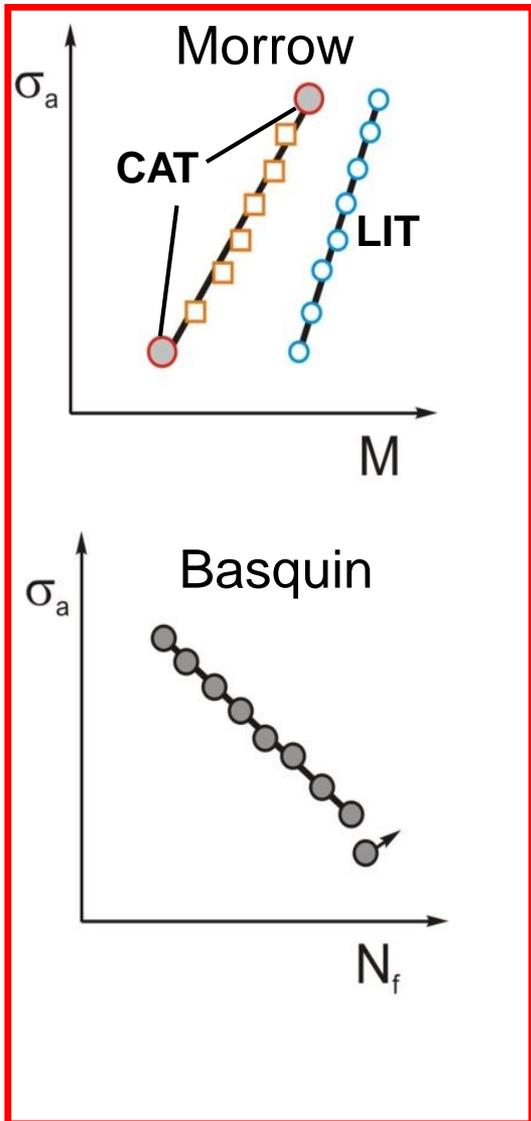
- FreeCommander XE**: File manager showing a folder named 'Papierkorb'.
- CamStudio**: Video recording software. The interface shows recording status: 'Start recording: 2015-08-21 12:02:16.95', 'Limited recording: On, 1750 ms', 'Current Frame: 1480', 'Current File Size: 25.57 Mb', 'Actual Input Rate: 5.23 fps', 'Time Elapsed: 0 hrs 1 min 14 secs', 'Number of Colors: 32 Bits', 'Codec: Microsoft Video1', 'Dimension: 1600 X 900'. A 'Press the Stop Button to stop recording' message is visible.
- Windows PowerShell ISE**: Opened to a script file 'Skript.ps1' with the following content:

```
Logfile Writer Pro... - x  
Logfile Filtering Server mms  
Mode Max size  
Log to this file 1000 KB  
C:\Users\Georg\Documents\Arbeit\SMART-NEST\2_Bearbeitung\zb_Messungen\2015-08-21\zug1\P3.txt  
Log each cycle Log now!  
Store task documentation
```
- Logfile Writer Pro...**: A window for configuring logging, showing the same file path as PowerShell.
- Cycle Controller (rev 3)**: A control interface with a 'STOP' button and settings for measurement frequency and duration.
- Taskbar**: Shows the system clock at 12:02:16.95 and 12:02:17.96, and several open tasks including 'Windows Power...', 'Zug1 - FreeCom...', 'MMS', 'Hardware und S...', 'Task-Manager', and 'CamStudio'.





Fatigue Life Calculation Method "PHYBAL"



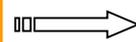
$$\sigma_a = K' \cdot (\varepsilon_{a,p})^{n'}$$



$$\sigma_a = K'_M \cdot (M)^{n'_M}$$



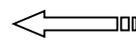
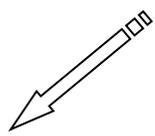
$$b_M = \frac{-n'_M}{5n'_M + 1}$$



**σ_a and N_f
of one CAT**



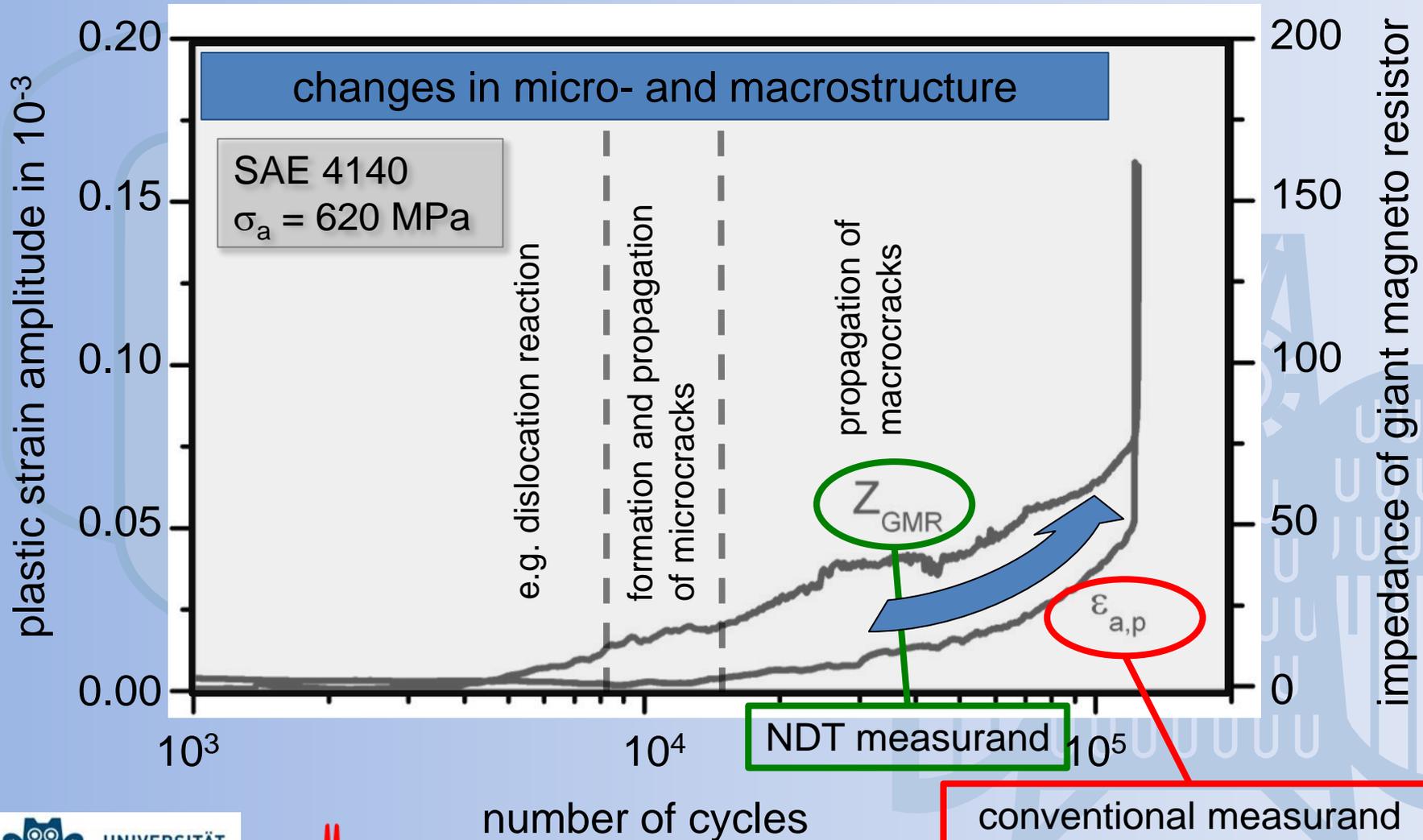
$$\sigma_a = \sigma'_{f,M} \cdot (2N_f)^{b_M}$$



$$N_f = 0.5 \cdot \left(\frac{\sigma_a}{\sigma'_{f,M}} \right)^{\frac{1}{b_M}}$$



Cyclic Deformation Behavior





Conclusions

- Life cycle management of ageing steel infrastructure can be made more efficient with NDT and associated structural technologies
- The NDT and associated technologies are:
 - Magnetics or other technologies to measure actual stress, strain and loading conditions
 - Damage tolerance ,redesign‘
 - Material residual fatigue life assessment with PhyBaL
 - Magnetics for the assessment of the damage and stress condition in the pre-cracked phase.
 - Prognostics for the assessment of residual fatigue life.



Acknowledgement

Parts of the research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under REA grant agreement n° 284995

