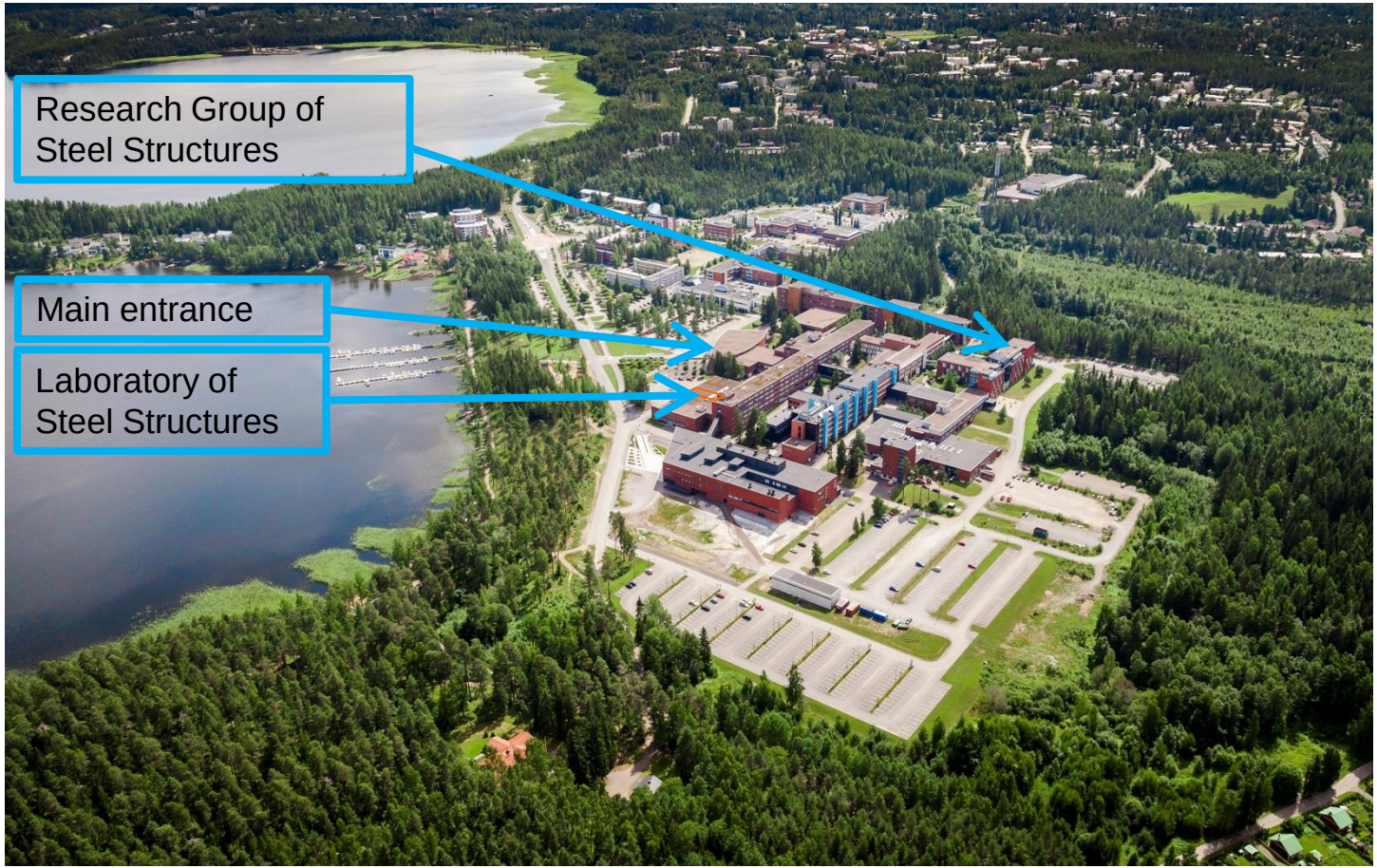
LUT University

Mechanical Engineering

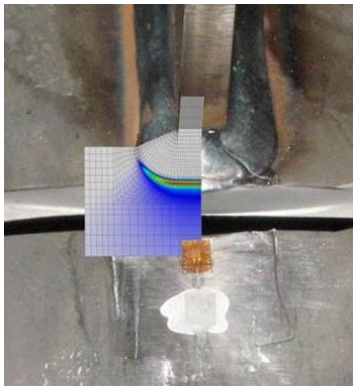
Laboratory of Steel Structures

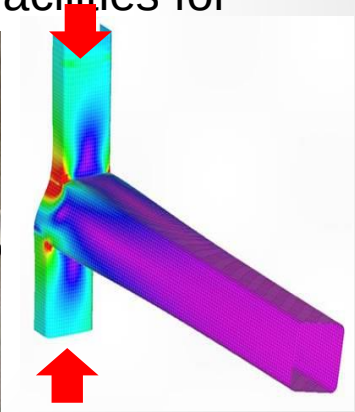


LUT University

STEEL STRUCTURES

- Research group of Steel Structures is working on design and fabrication of metal structures for demanding energy-efficient applications
- We are creating novel ideas and rules for design and fabrication procedures especially for design with high- and ultra-high strength steels (UHSS)
- The investigation includes theoretical analyses, numerical simulation and experimental testing. Laboratory of Steel Structures has good facilities for testing, also at low ambient temperatures
- Current main research topics include
  - Fatigue and static strength of welded joints
  - Performance of welded structures made of UHSS
  - Simulation and measurement of residual stress and their effect on structural behavior of structures
  - Digitized life cycle control including design, fabrication and service of metal constructions





RESEARCH TOPICS – STEEL STRUCTURES

a) Design of steel structures

b) Analyzing the behavior of steel structures imposed to different load conditions

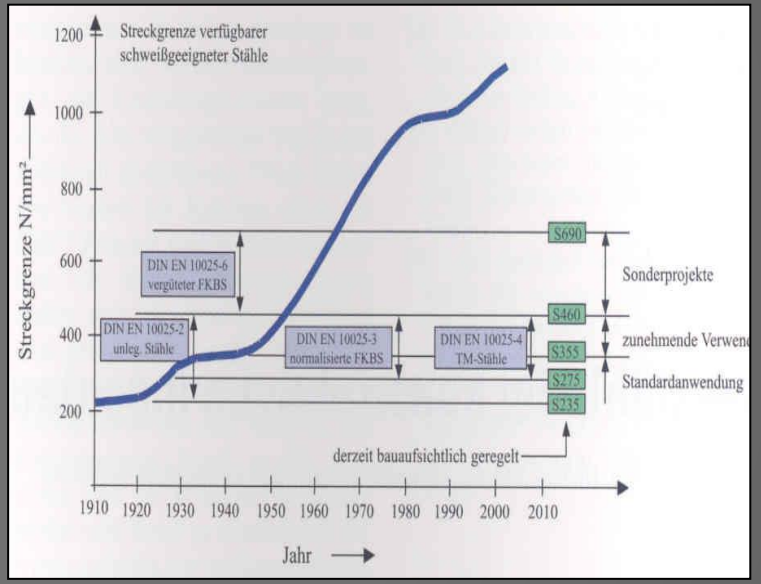
- Especially capacity of welded joints
- Static and ***fatigue*** strength made of high or ultra-high strength steels

  → ENERGY EFFICIENCY
- Digitization of the production (design and fabrication)
- supporting topics: FEA, simulations, experimental static/fatigue testing, arctic conditions

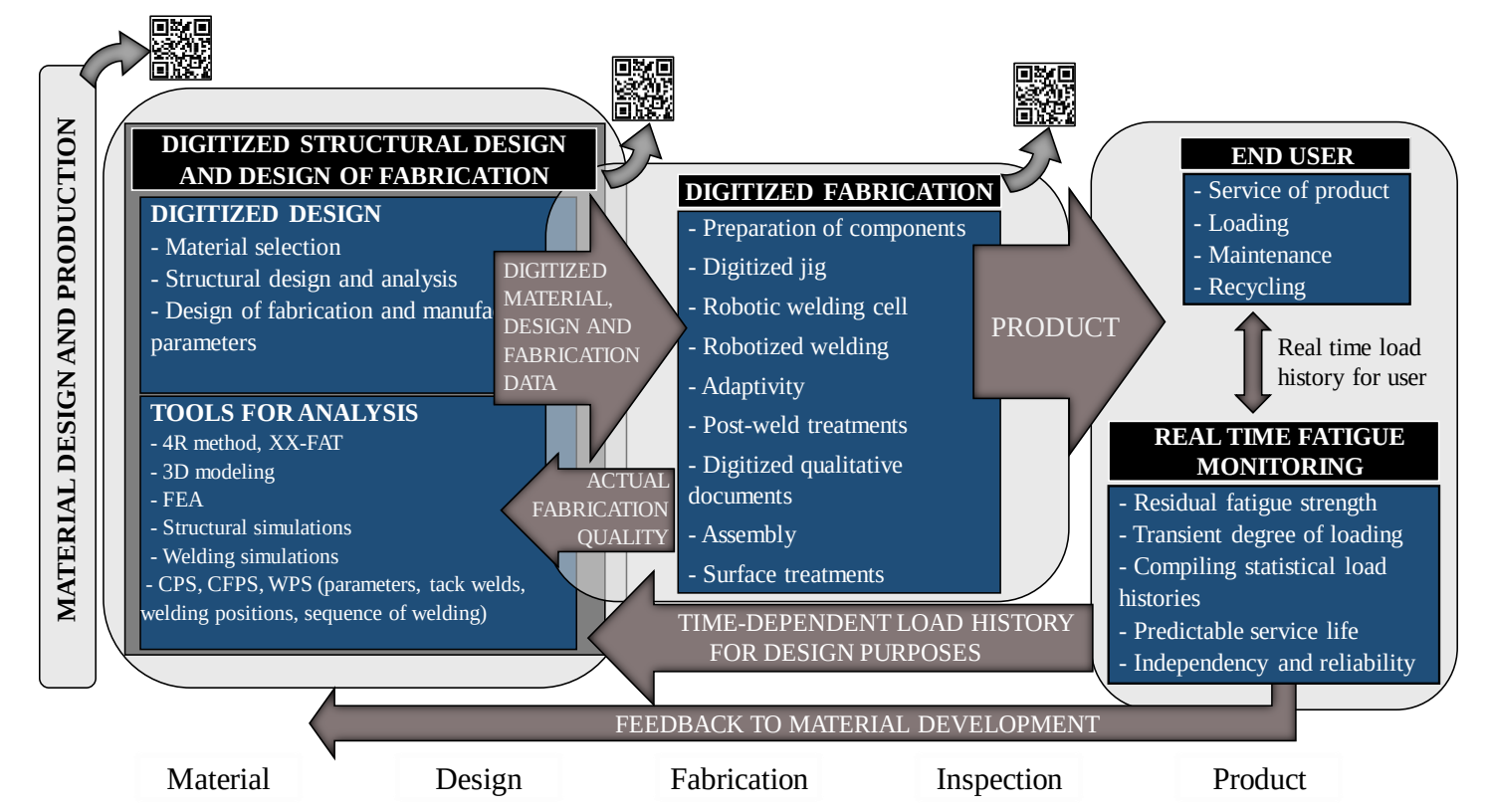
c) Collaboration with Finnish industrial companies

d) International cooperative universities

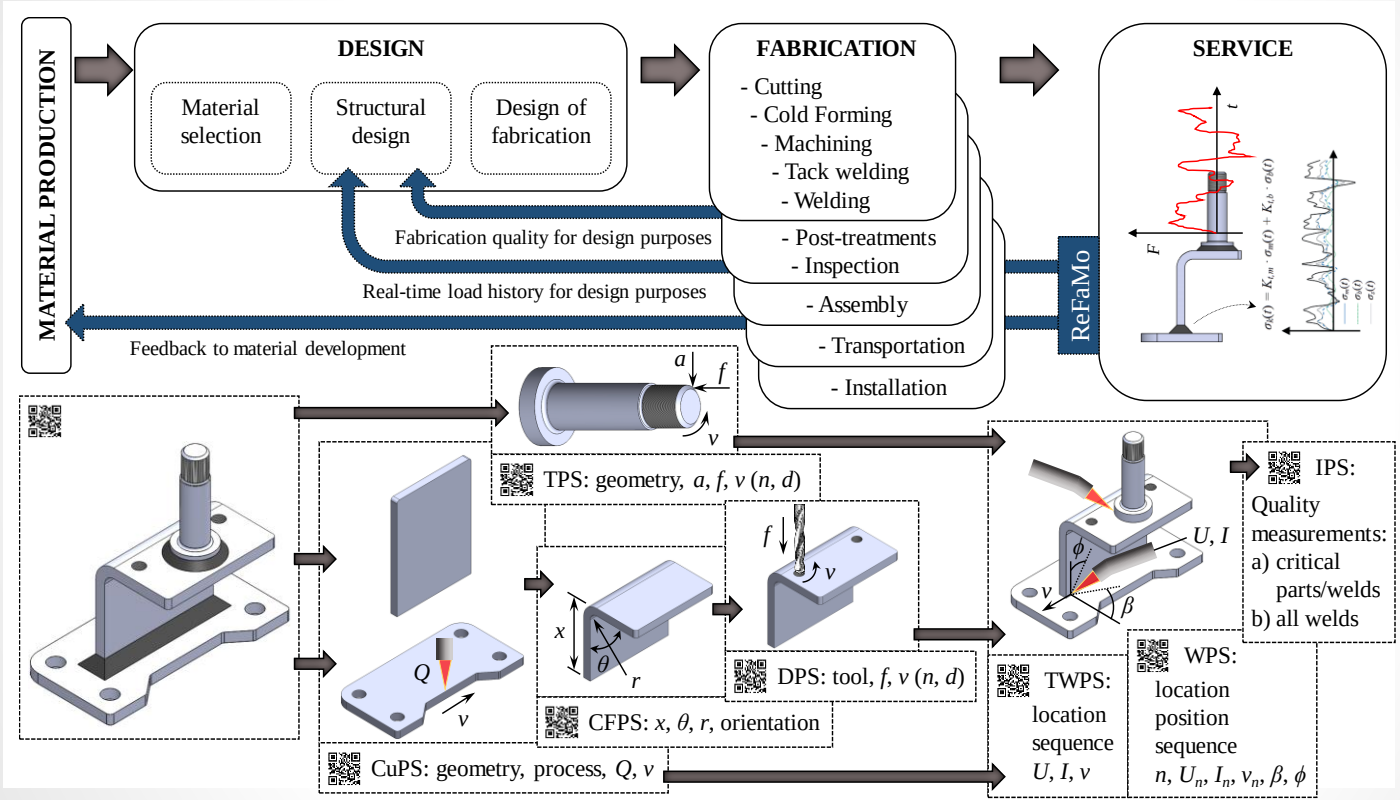
Increase of material strength in structural steels



DIGITIZED DESIGN AND FABRICATION



DIGITIZED PRODUCTION

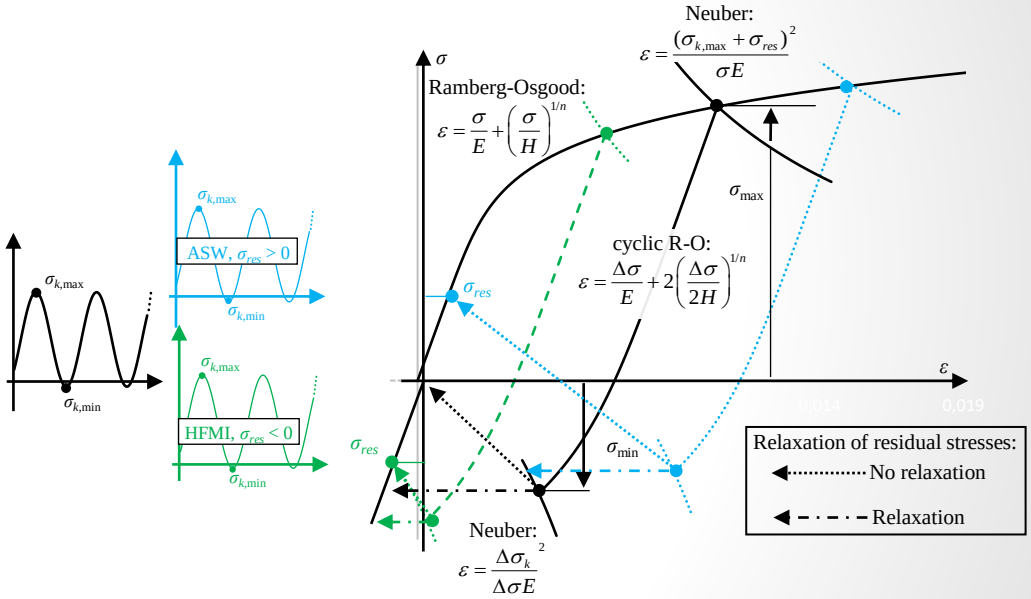


4R METHOD FOR FATIGUE DESIGN OF WELDED JOINTS AND COMPONENTS

Novel multi-parametric fatigue assessment approach that considers:

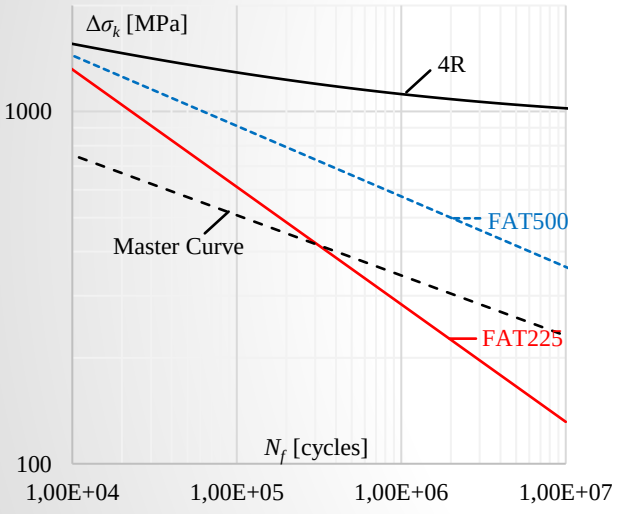
- Material ultimate strength ($\boldsymbol{R_m}$)
- Residual stresses ($\boldsymbol{\sigma_{res}}$)
- External stress ratio ($\boldsymbol{R}$)
- Weld toe radius ($\boldsymbol{r_{true}}$)

Acting stress ratio (R_{local}) at notch root is obtained using well-known material models (Ramberg-Osgood and Neuber's notch theory) considering the four essential parameters

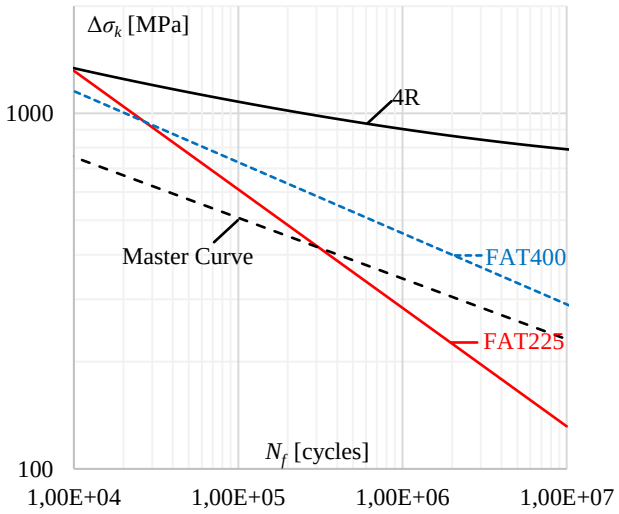


S-N CURVES OF 4R METHOD

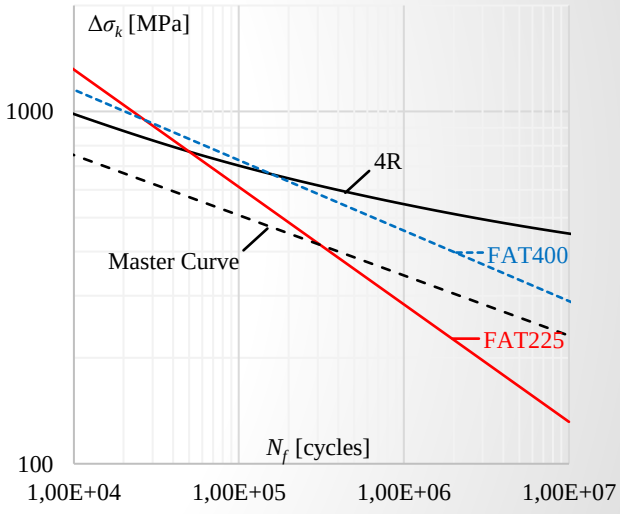
Material S1100 | Loading R = -1 | σ_{res} = -460 MPa



Material S700 | Loading R = -1 | σ_{res} = -330 MPa



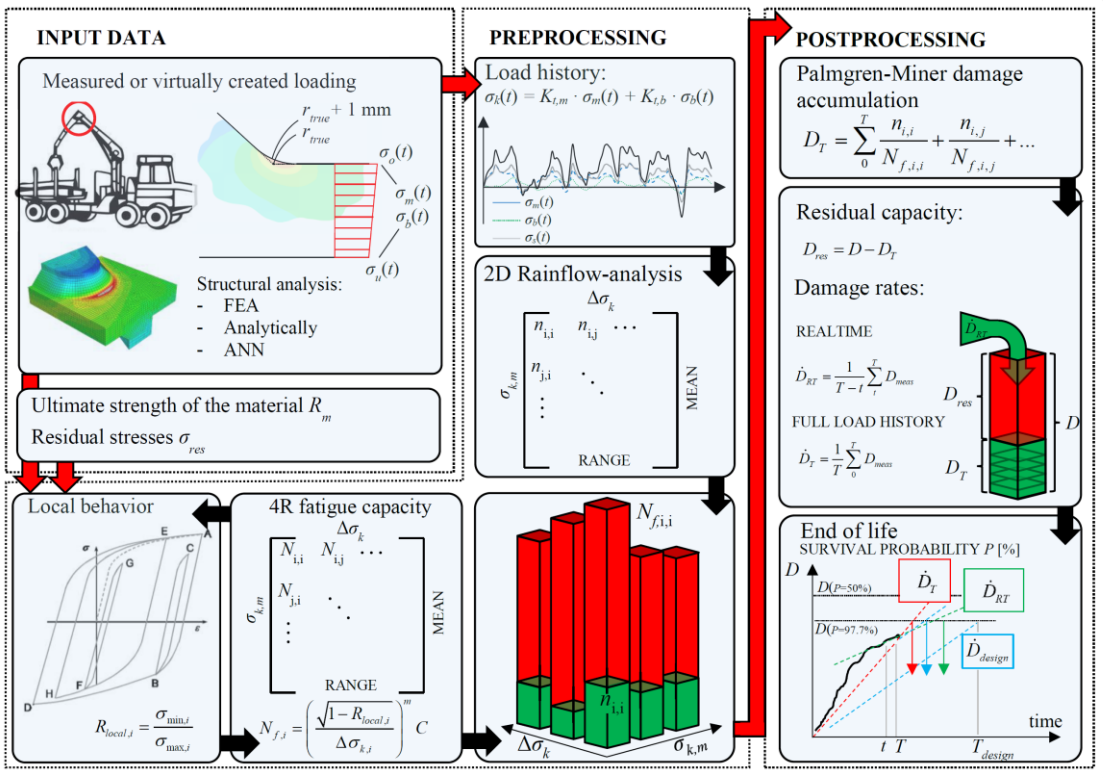
Material S700 | Loading R = 0 | σ_{res} = -330 MPa



REFAMO – REAL-TIME FATIGUE MONITORING

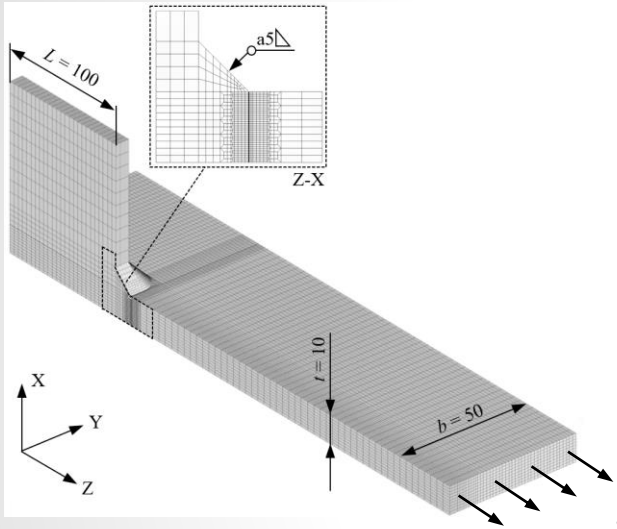
ReFaMo measures, analyses the measured loading, and calculates and visualizes the remaining 4R fatigue life and current degree of loading

ReFaMo solves the problems related to processing of large amount of measured data, structural health monitoring and inaccuracy of design loads



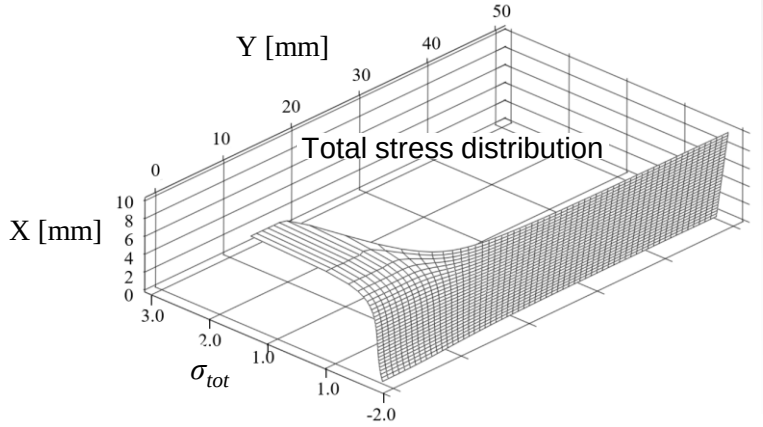
CATEGORIZATION OF STRESS COMPONENTS

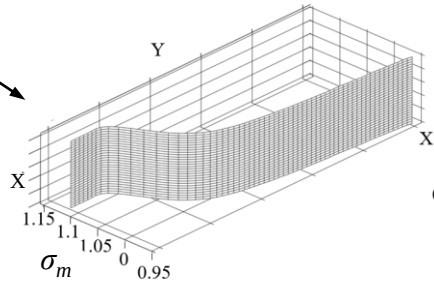
UNDER AXIAL LOADING



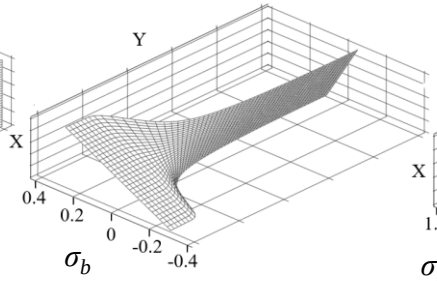
$$\sigma_s = \sigma_m + \sigma_b$$

$$\sigma_{tot} = \sigma_m + \sigma_b + \sigma_{nlp}$$

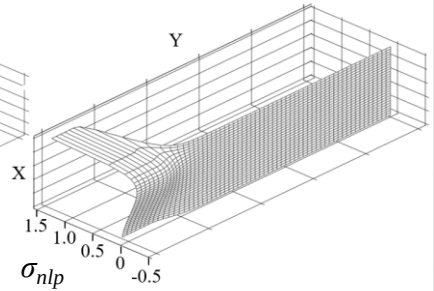




Membrane stress distribution



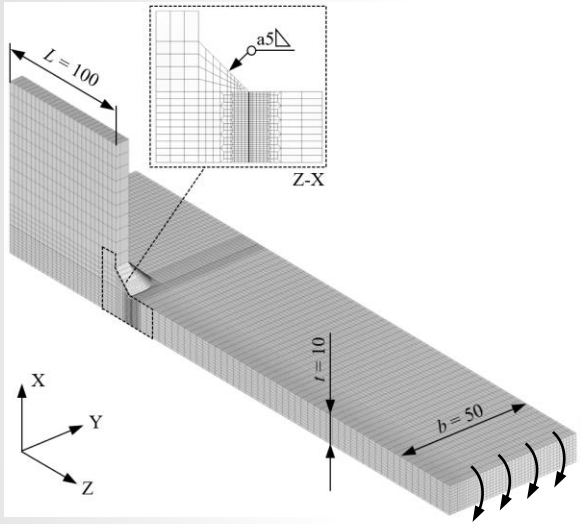
Bending stress distribution

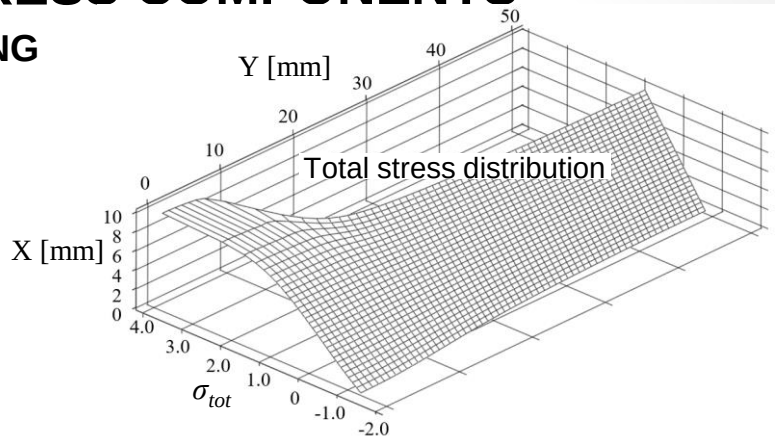


Non-linear stress peak

CATEGORIZATION OF STRESS COMPONENTS

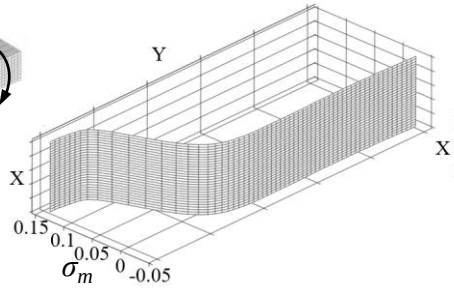
UNDER BENDING LOADING



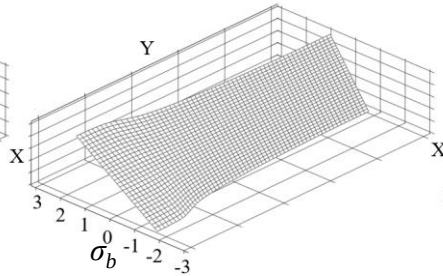


$$\sigma_s = \sigma_m + \sigma_b$$

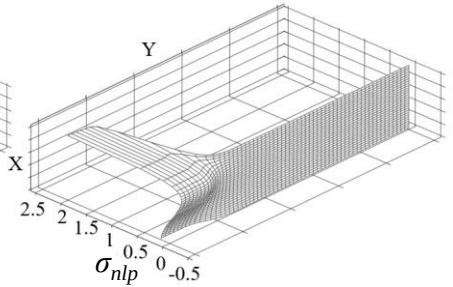
$$\sigma_{tot} = \sigma_m + \sigma_b + \sigma_{nlp}$$



Membrane stress distribution



Bending stress distribution



Non-linear stress peak

Research team

TIMO BJÖRK
Professor
Head of the laboratory

KALLE LIPIÄINEN
Junior Researcher

SHAHRIAR AFKHAMI
Post-Doc

ANTTI AHOLA
Post-Doc

Pasi Tanskanen
Post-Doc

MEHRAN GHAFOURI
Junior Researcher

HAMIDREZA ROHANI RAFTAR
Junior Researcher

PhD s Students/Researchers from industry

HELI METTÄNEN

SAMI HEINILÄ

TERO PESONEN

RIKU NEUVONEN

MATTI KOSKIMÄKI
Laboratory Engineer

OLLI-PEKKA PYNNÖNEN
Laboratory Technician
(instrumentation, measurements)

JARI KOSKINEN
Laboratory Technician
(instrumentation, measurements)

MIKA KÄRMENIEMI
Laboratory Technician
(Welding, preparation of specimens)

JAN MUURONEN
Laboratory Technician
Machining, preparation of specimens

No. of Master Thesis Workers at LUT: 2 (11/2022)

”Theory and experiments should be thought

of as completing each other,

and the engineer who takes this attitude will, in general, be a more effective problem solver than one who neglects one or the other of these two approaches.”

Ernest O. Doebelin

Department of Mechanical Engineering
The Ohio State University

LUT University

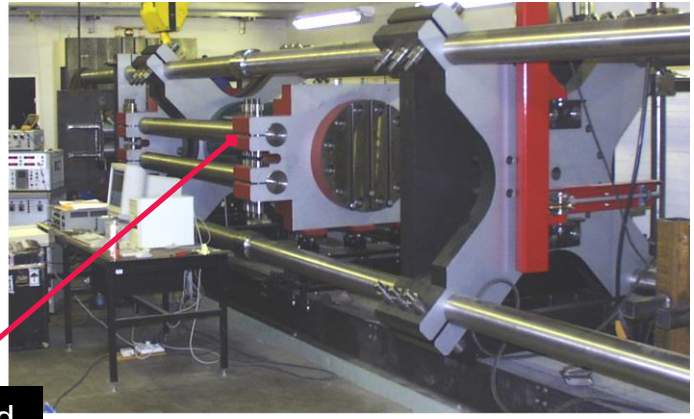
Mechanical Engineering

Laboratory of Steel Structures

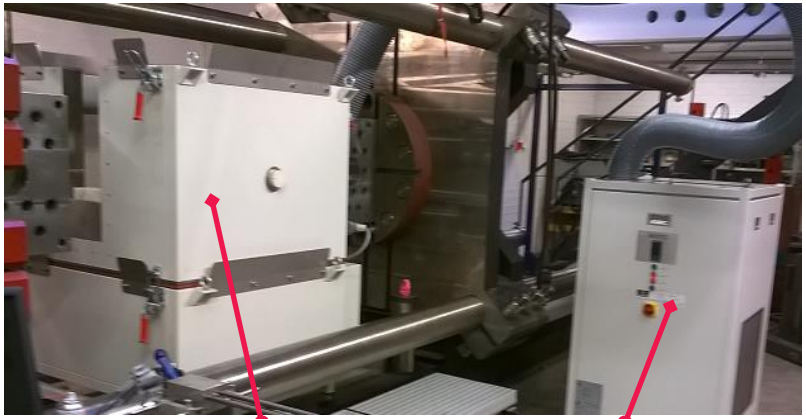
Research Facilities

MATERIAL TESTING MACHINES (LOAD FRAMES)

- Laboratory have seven (7) servo hydraulic load frames for dynamic and static loading test set-ups.
- Biggest test rig in Finland for dynamic testing up to 5 MN compression and tension loading.
    - Equipped with movable environment chamber down to -60°C to determinate material and connections behaviour at sub zero temperatures.
    - Full-scale tests of components made of high- and ultra-high-strength steels (S700-S1100).



5MN load frame



Environment chamber + Cooling unit

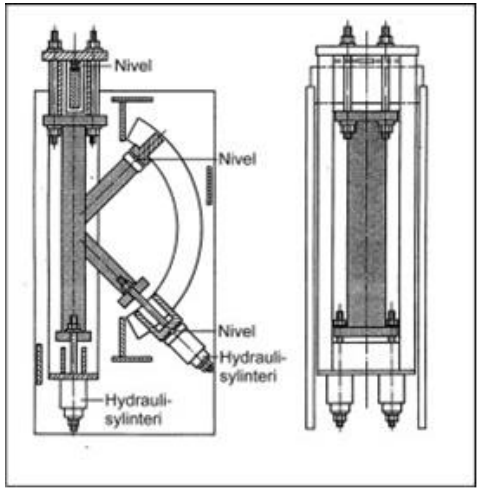
MATERIAL TESTING MACHINES (LOAD FRAMES)

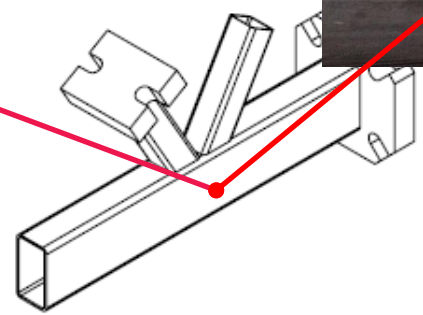
- RUMUL Vibroforte 700 high frequency testing machine, April/2022
- 5 MN for static and dynamic loading
- 1200 kN and 750 kN for dynamic and static loading
- 400 kN for dynamic and static loading
- Hz1 and Hz2 frames for 150 kN dynamic and static loading
- 150 kN for dynamic and static loading
- 1 MN compression up to 7 m length columns and beams
- Drop weight testing machine for impact tests

MATERIAL TESTING MACHINES (LOAD FRAMES)

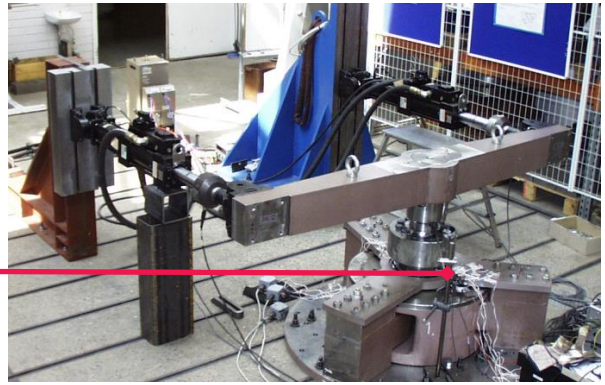
- Load frame for RHS K-joints
  - Designed in Laboratory of Steel Structures based on the knowledge of 30 years of testing experience
  - Static chord force up to 2 MN and diagonal force up to 1.2 MN

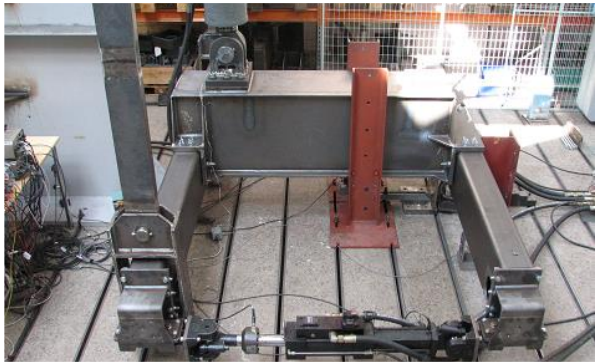
    Cooling capability for subzero tests down to -60°C





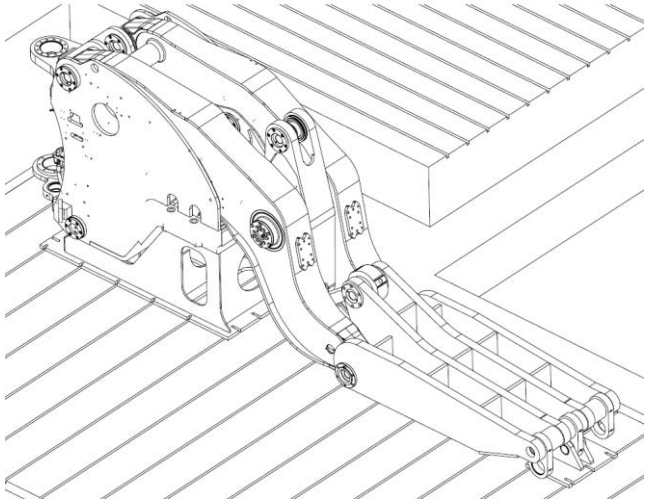
FULL-SCALE TEST SET-UPS
DYNAMIC AND STATIC LOADING





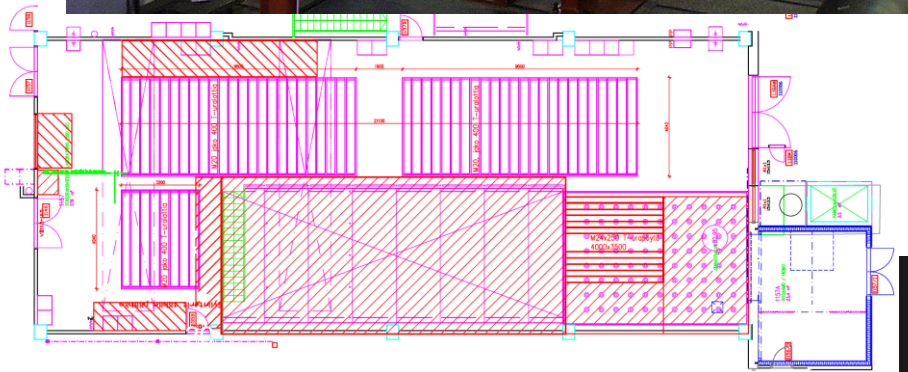
FULL SCALE TEST SETUPS
DYNAMIC AND STATIC LOADING

- Main frame of Underground Loading and hauling machine



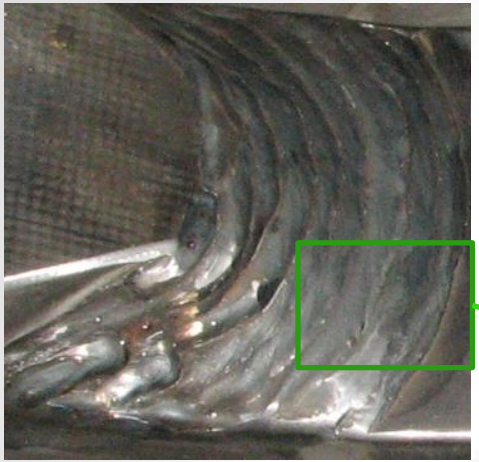
FULL SCALE TEST SETUPS
DYNAMIC AND STATIC LOADING

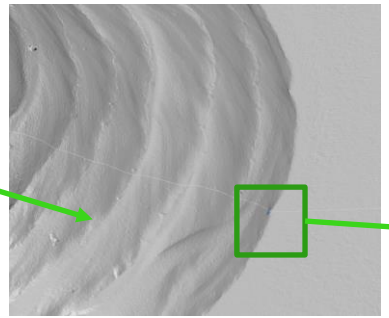
- Lab floor space: 11 m x 29 m = 319 m^2
  - height 4.5 m (hoist)
- T-slot M20 floor areas with 400 mm spacing.
  - 2 x (9,6 m x 4 m) , total length of 21 m
  - 4 m x 3,2 m
- T-slot loading table 4 m x 3.5 m (M24 - 250)

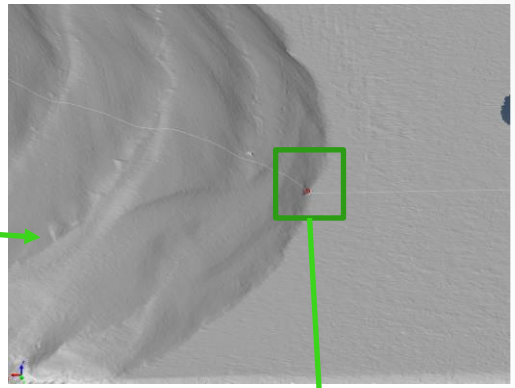


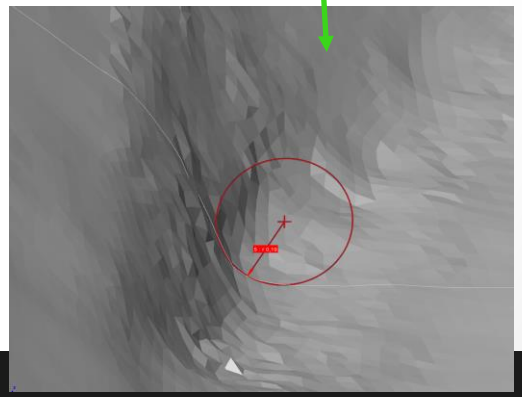
MEASUREMENTS of SPECIMENS

HP-L-20.8 Laser Scanner for ROMER Absolute Arm







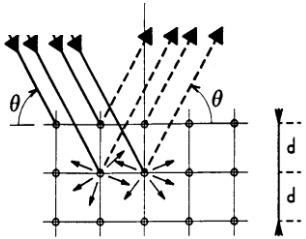


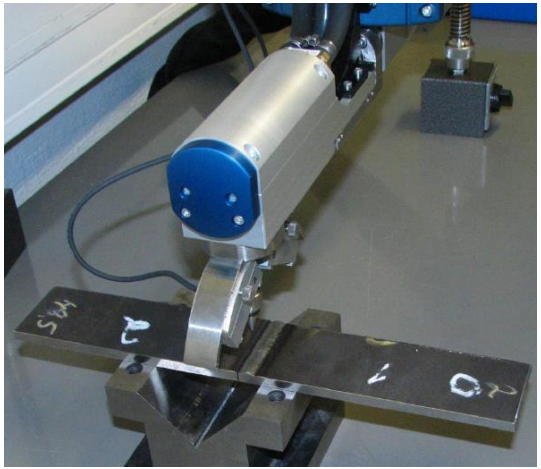
Detailed 3D-2D-geometry for fatigue analysis

MEASUREMENTS OF SPECIMENS

- X-ray diffraction device for residual stress measurements

$$\lambda = 2d \sin\theta$$

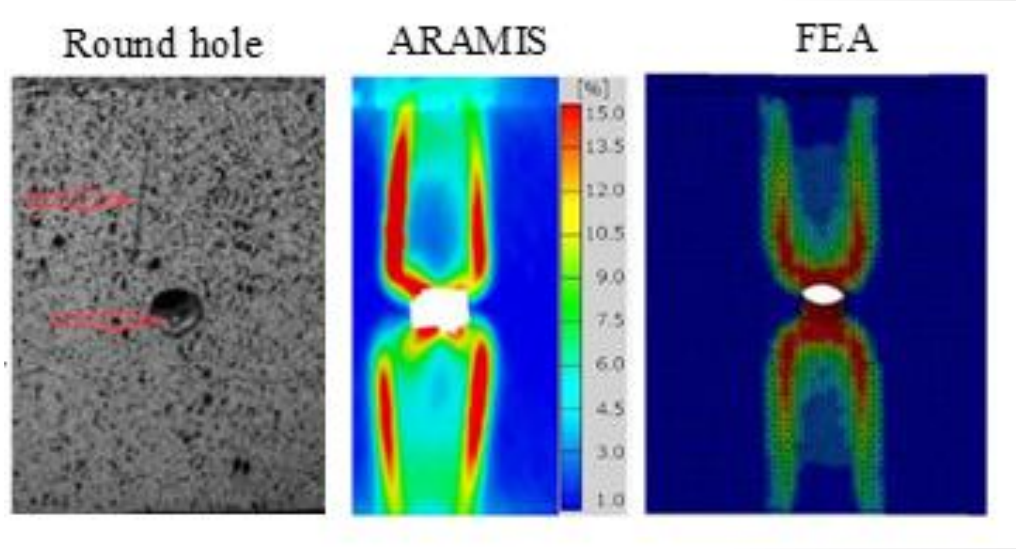




MEASUREMENTS OF SPECIMENS

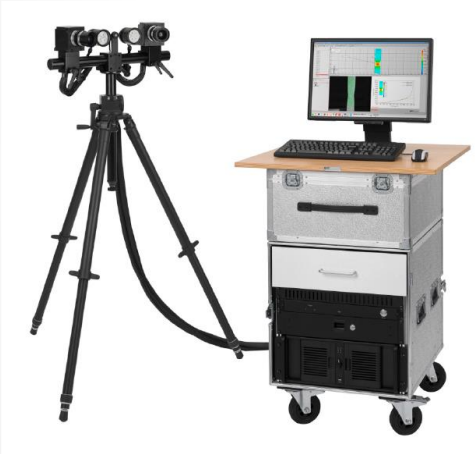
Optical 3D Deformation Analysis, Digital image correlation (DIC) device with 12MPa cameras

ARAMIS

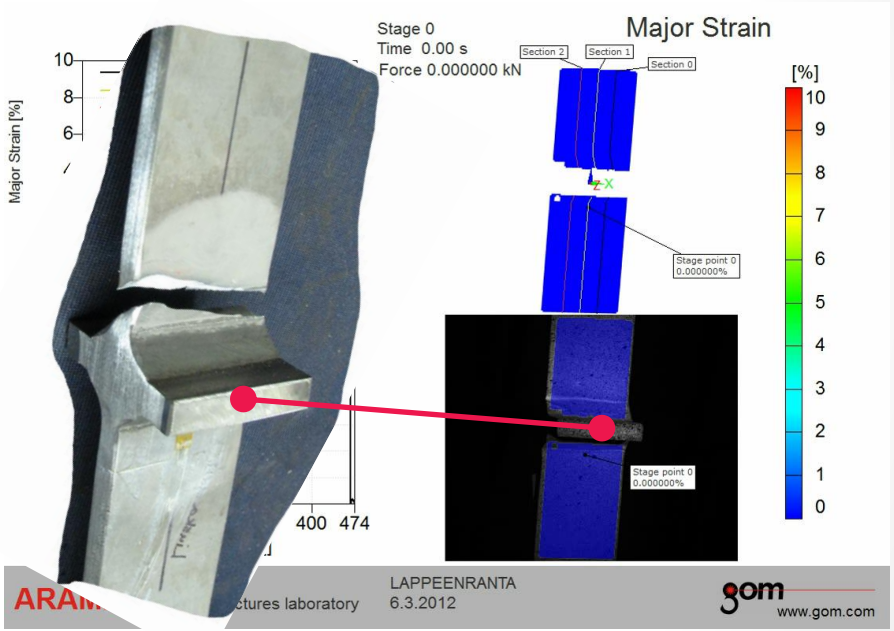


MEASUREMENTS OF SPECIMENS

Optical 3D Deformation Analysis, Digital image correlation (DIC) device with 12MPa cameras

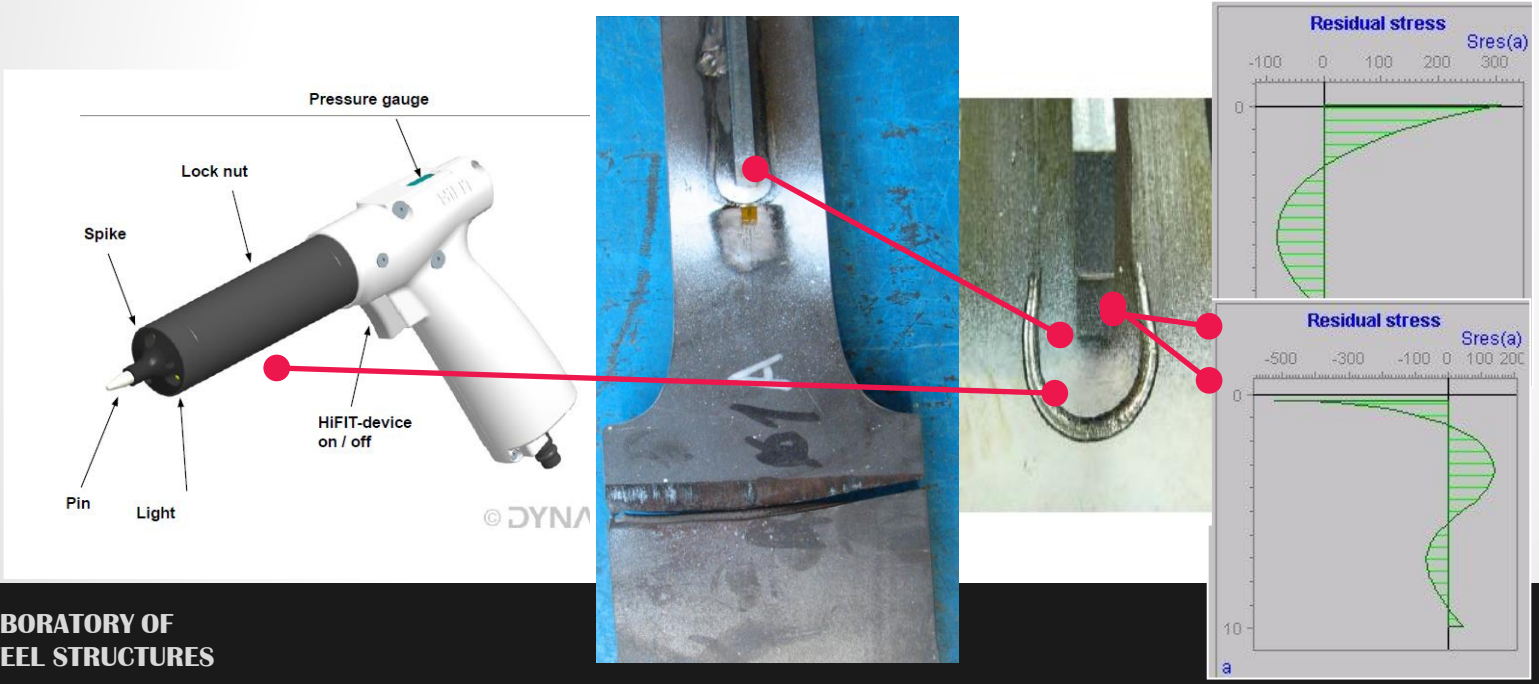


ARAMIS



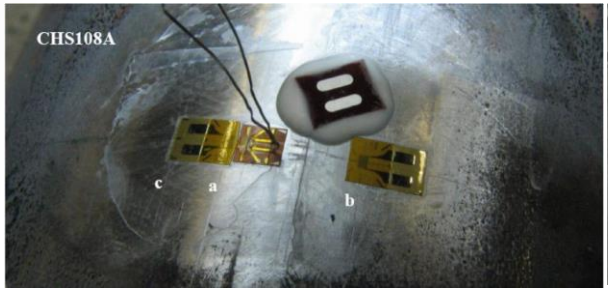
High Frequency Mechanical Impact Treatment (HFMI)

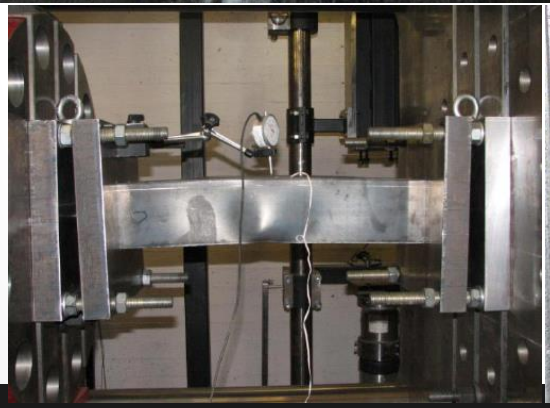
- Improvement of fatigue of welded structures as much as 5 times better fatigue life.
  - As welded condition FAT95% =97 vs. HFMI treated condition FAT 95% =175

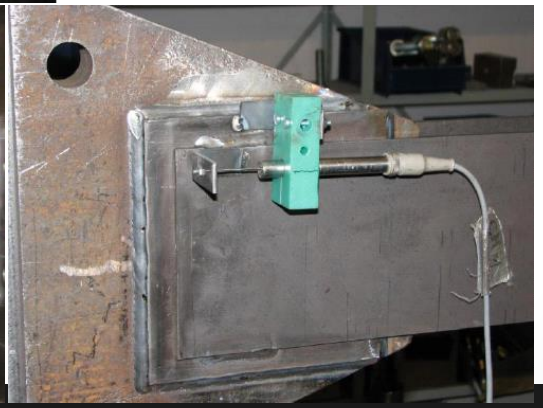


INSTRUMENTATION

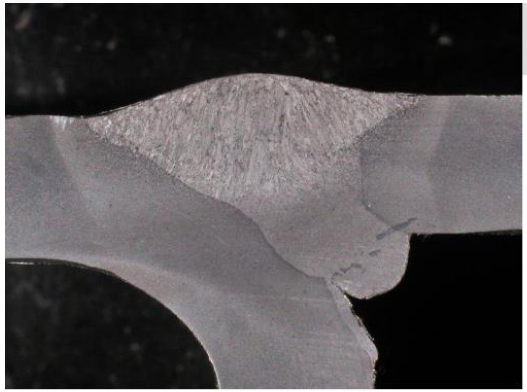
- Strain Gauges, Transducers, Aplifiers, Data Acquisition.

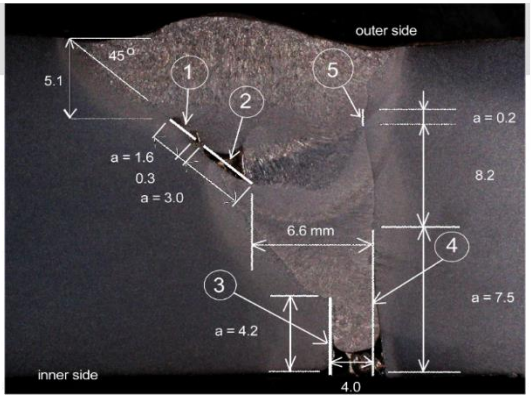


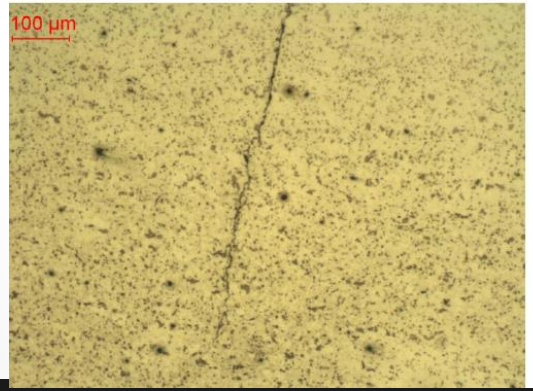


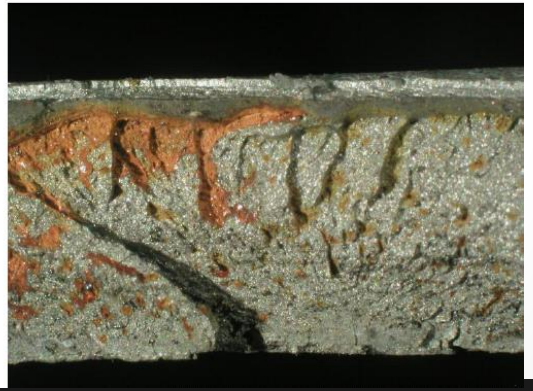


MICROSECTIONS and FIGURES



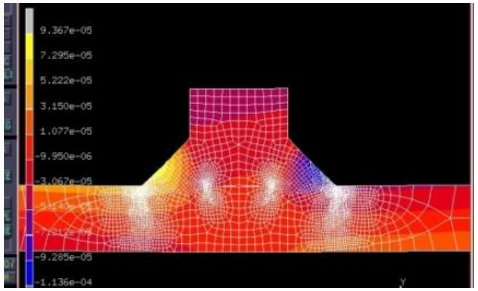


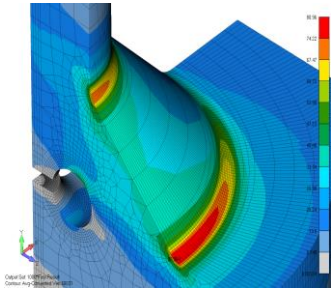


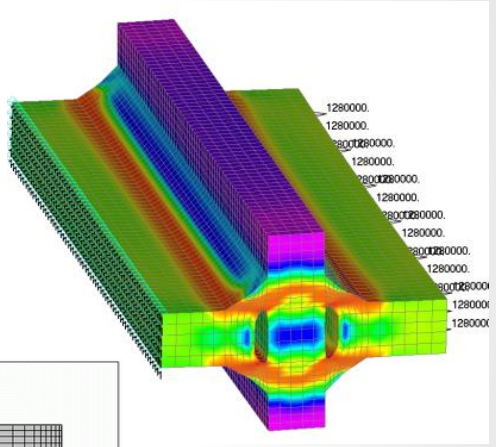


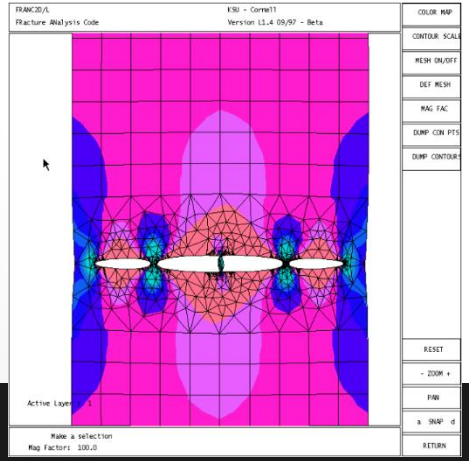
TOOLS for CALCULATION AND ANALYSIS

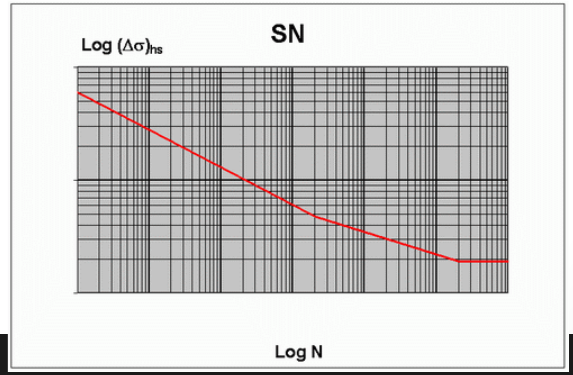
- FEA: ABAQUS, FEMAP/Nastran, Franc2D, LS/DYNA, tailor-made programs
- Others: Mathcad, Mathlab, Solidworks, AutoCad, etc..





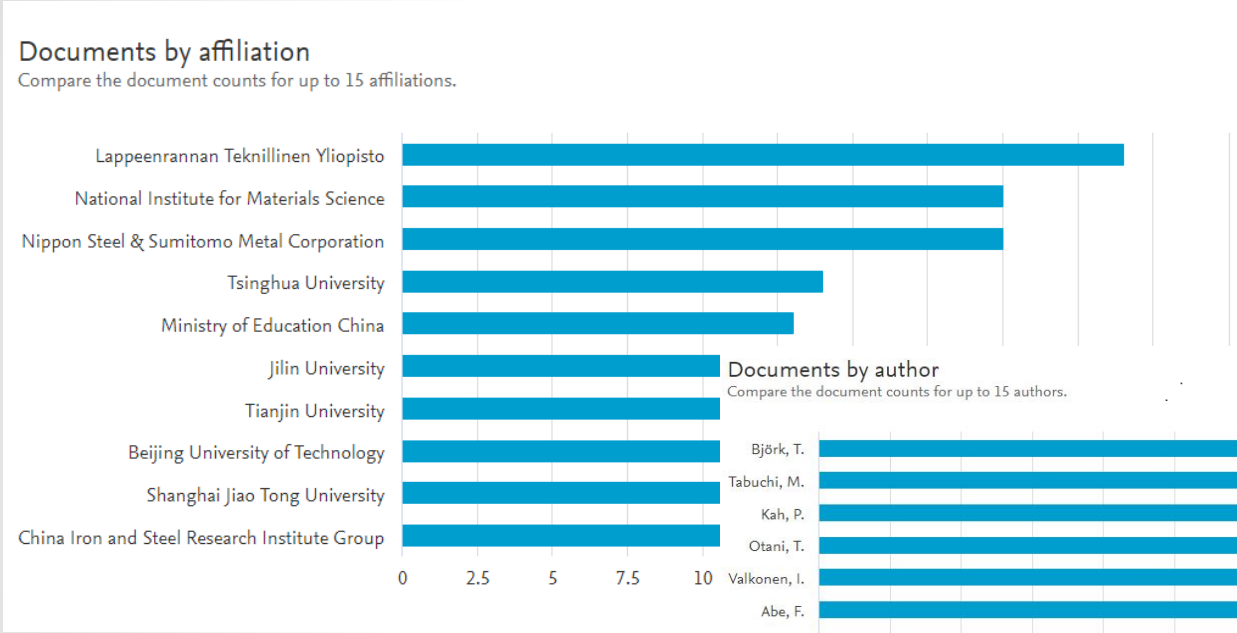


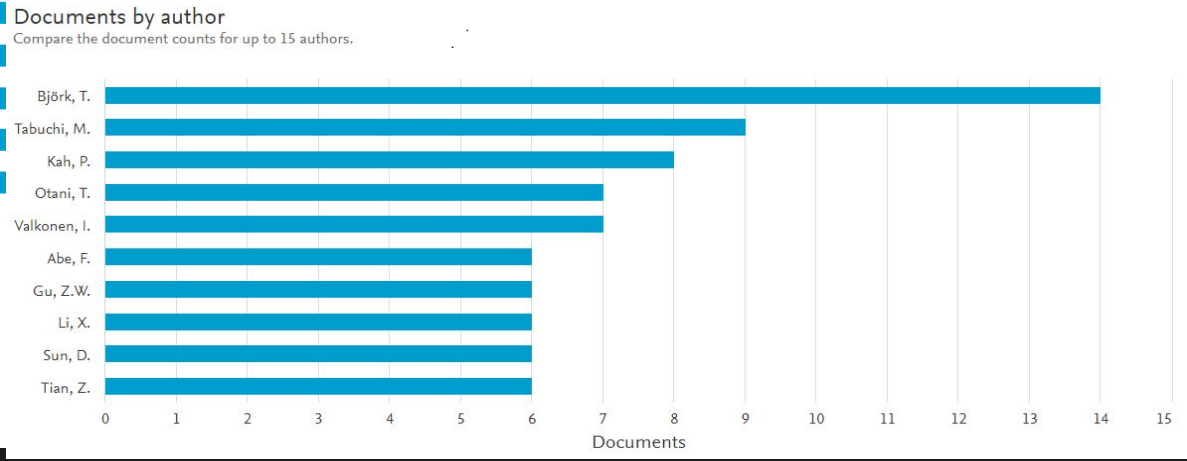




LUT University

LUT SCOPUS: Welded UHSS (Weld+Ultra+High+Strength+Steel)





HRO SUUNNITTELUFOORUMI
www.lut.fi/hro

- Teräsrakenteiden laboratorion koordinoima foorumi vaativien rakenteiden suunnittelijoille, tuotekehittäjille ja tutkijoille sekä valmistuksesta, tarkastuksesta ja kunnossapidosta vastaaville
- SHY:n Suunnittelufoorumi
- Yhteensä 38 + jäsenyritystä

- Tavoitteet:
  - ✓Tuottaa uutta tutkimustietoa (tutkimusprojektit + HRO diplomityöt)
  - ✓Toteuttaa Suomen hitsaavan teollisuuden kannalta tärkeitä tutkimusprojekteja (BF, SA, EU..)
  - ✓Välittää uusin tarpeellinen tutkimustieto maailmalta kotimaiselle teollisuudelle (IIW)
  - ✓ Luoda ja ylläpitää alan yritysten välisten yhteistyötä ja kontaktointia
  - ✓Tuottaa palvelututkimusta ja koulutusta yrityksille (HRO alennus jäsenyrityksille)

- HRO Suunnittelufoorumin teemapäivät
  - ✓Alan viimeisimpien tutkimustulosten esittely (LUT + tutkimuslaitokset)
  - ✓Jäsenyritysten ja kutsuvieraiden omat esitykset
  - ✓Kansainvälinen vieraileva luennoitsija
  - ✓Kaksipäiväiset vuosittain

NEED MORE INFORMATION?
WE ARE HERE FOR YOU,
DO NOT HESITATE TO ASK

- Professor Timo Björk: Timo.Bjork@lut.fi
- Laboratory Engineer Matti Koskimäki: Matti.Koskimaki@lut.fi

STEEL STRUCTURES