Matematisk modellering av ultraljuds-inspektion vid återkommande provning

-utmattnings respektive spänningskorrosionssprickor

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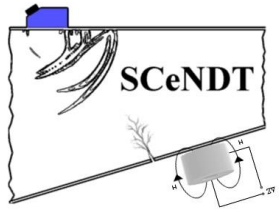
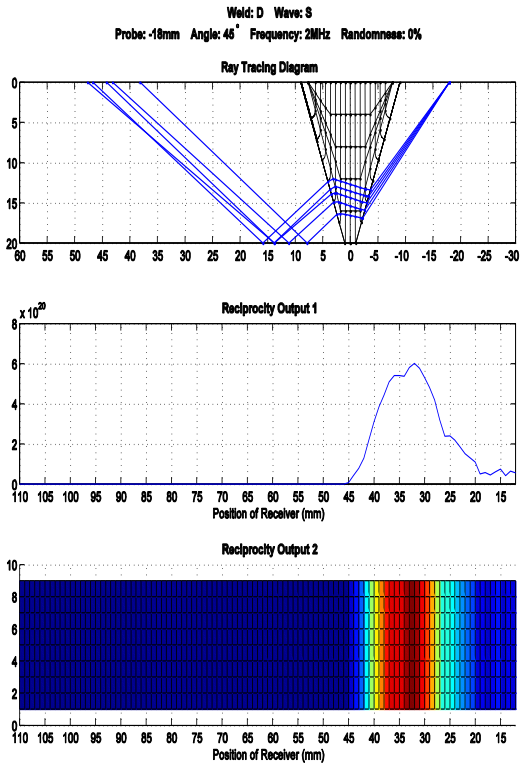
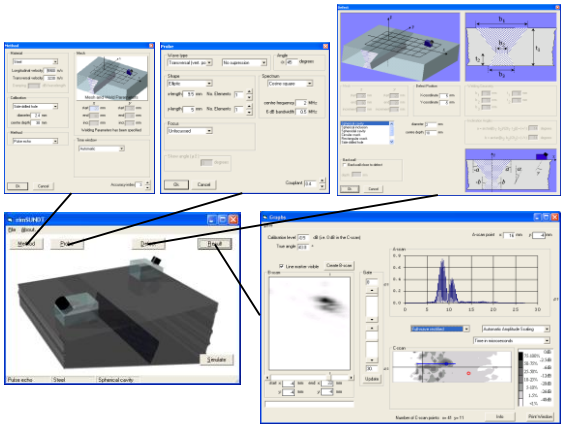


Advanced NDT
- Integrity and quality assessment by NDE (IqNDE)



Håkan Wirdelius	Professor
Gert Persson	Associate Professor
Peter Hammersberg	Lecturer
Anders Rosell	post doc, GKN (20%)
Maria Semenova	PhD Student (Q3 2017)
Xiangyu Lei	PhD Student (Q1 2018)



SCeNDT

Research area

- *Applied mathematical modelling of NDE methods*
  - Develop and experimental validation of mathematical models of different NDE methods
  - Apply mathematical modelling in the development of NDT as a tool for material characterization (NDC)
  - Use mathematical modelling in the development of new NDT techniques

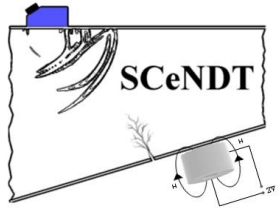
- *Integrity and quality assessment by NDE (IqNDE)*
  - Risk Based Quality Assessment (identification of risks, classification, probability of occurrence and probability of detection)
  - Generate Probability of Detection curves (POD) based on simulated data

Education

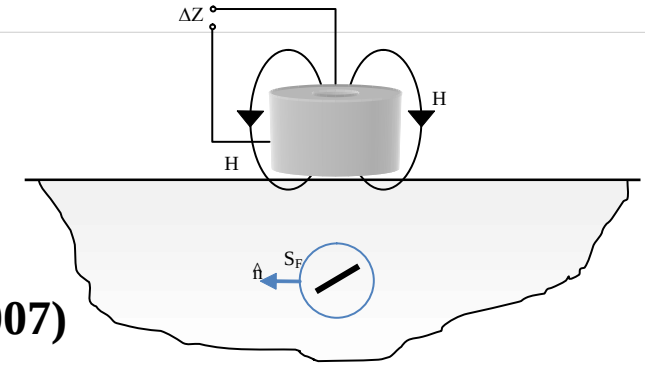
- ISI Technologies (graduate and PhD) ->

Non-Destructive Testing (NDT) in quality assessment and process control (19/20)

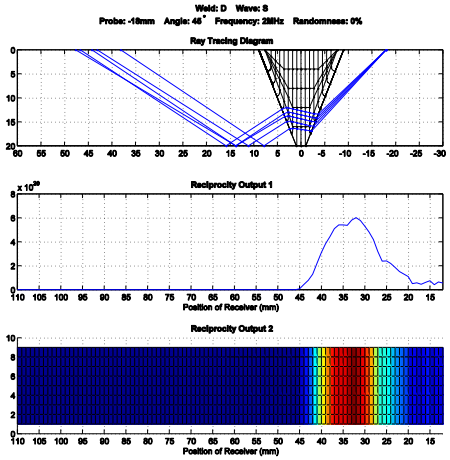
- Education for industry (graduate level)

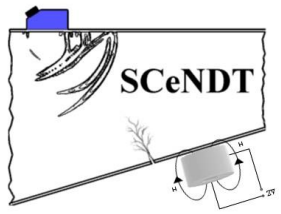


Previous and ongoing projects



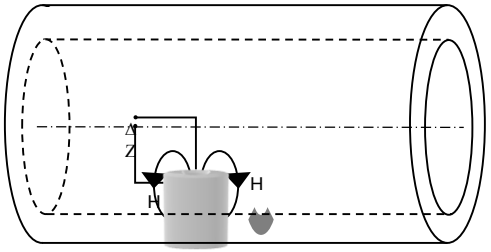
- **simSUNDT 1.2 delivered at a workshop 2004 (SQC)**
- **SCOD, a method to calculate the orientation of the dendrites in a weld based on UT data (Q. Liu, PhD 2007)**
- Quantification of the reliability of flaw detection for non-destructive techniques using probability of detection (POD) based on synthetic data, (Energimyndigheten)
- **PICASSO-imProved reliabIlity inspeCtion of Aeronautic structure through Simulation Supported POD,**
  - Analytical model of eddy current technique (T-matrix formalism) , (**L. Larsson, PhD 2014**)
  - Modeling of EC applied to weld geometries and properties, (**A. Rosell, PhD 2015**)
- Detection and classification of defects with digital RT applied to laser welded titanium, (**E. Lindgren, PhD 2015**)
- simSUNDT 1.2 -> 2.0 including immersion testing, phased array probes and anisotropic materials, (SSM)



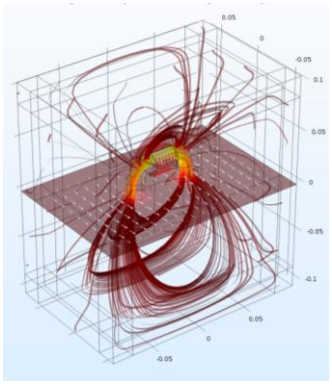


Previous and ongoing projects

Integrity and quality assessment by NDE - IqNDE

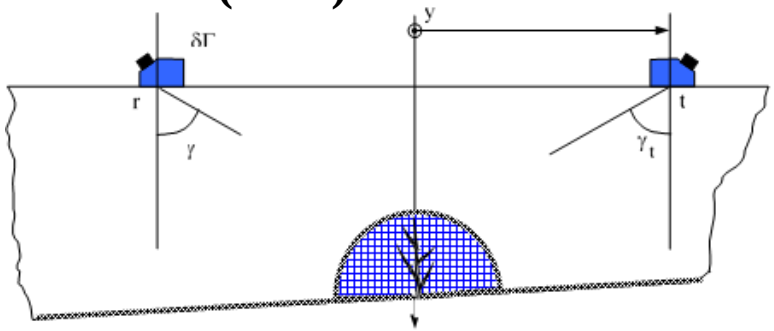


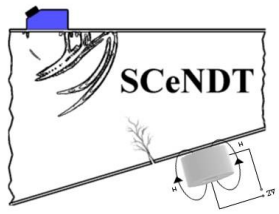
- Product Uniformity Control, 2013-2018, Research Fund for Coal and Steel (RFCS)
- Quality II (Swerea KIMAB) - POD baserat på simulerade data, 2015-2017, (Vinnova)
- FFI OFP4p Non-destructive characterization concepts for production (KTH) - Measurement system development of process monitoring in production, 2015-2018, (FFI Vinnova)



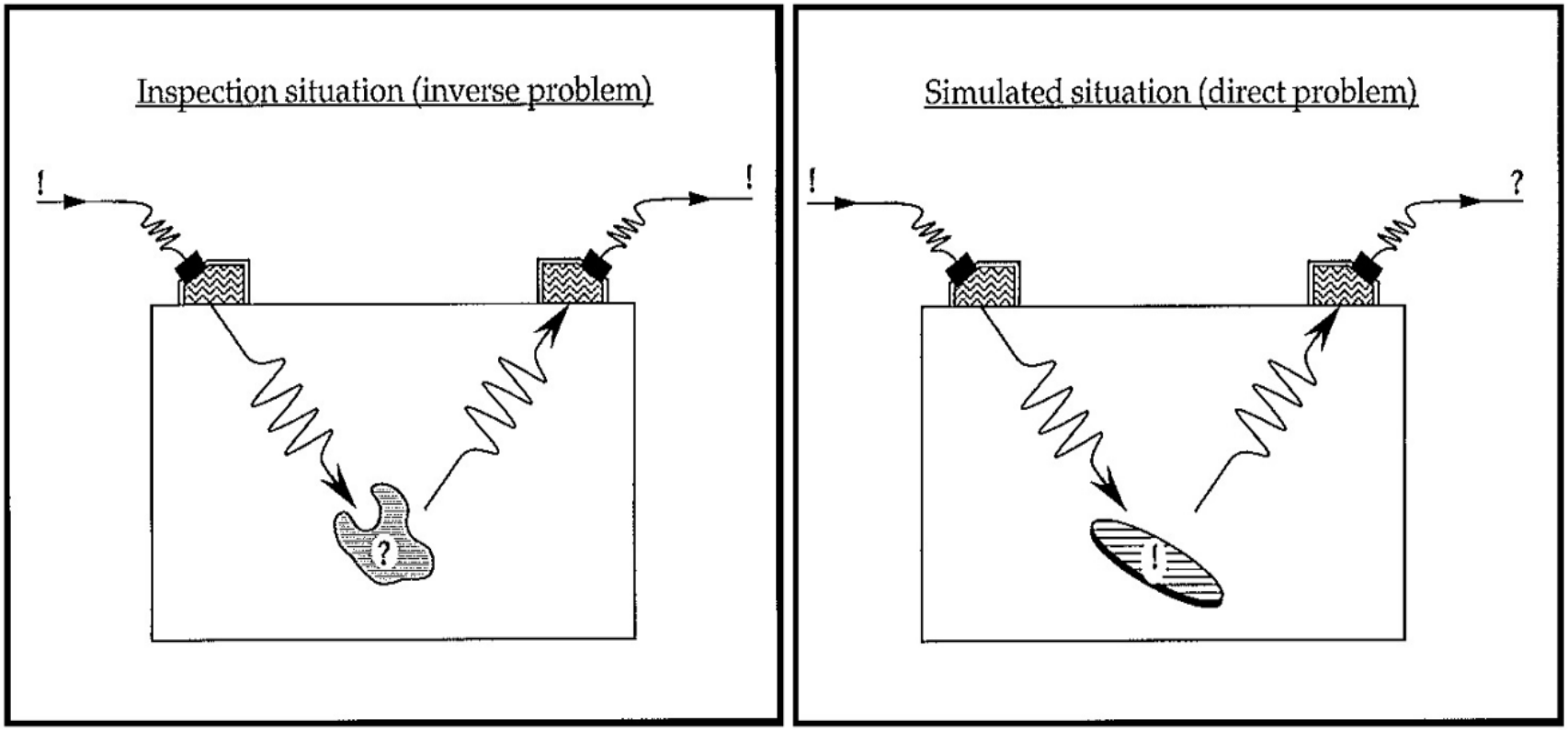
Applied mathematical modelling of NDE methods

- **Ultrasonic probe modeling and Nondestructive Characterization of Stress Corrosion Cracks (SSM)**

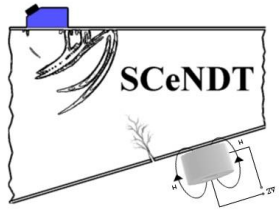




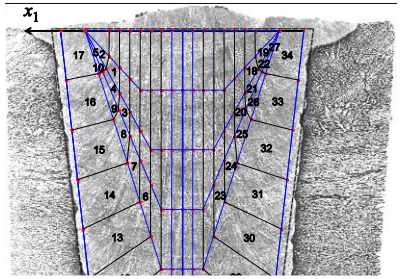
NDE is an inverse problem

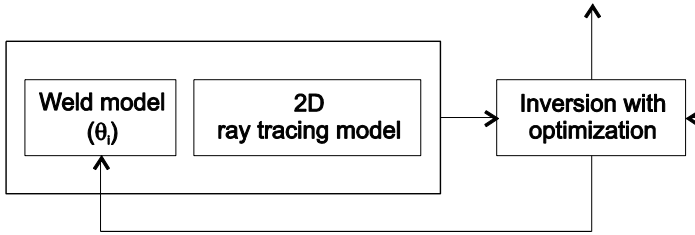


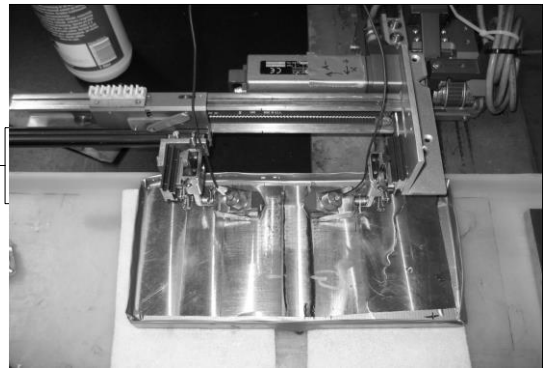
1. H. Wirdelius, “An Optimization Technique for Inverse Crack Detection”, J. of Modern Physics 5, 1202-1222, 2014.
2. Q. Liu and H. Wirdelius, “Estimation of grain orientation in an anisotropic weld by using a model of ultrasonic propagation in an inverse scheme”, Modelling and Simulation in Engineering, vol. 2014, Article ID 637476, 11 pages, 2014.
3. E. Lindgren, “Detection, 3-D positioning, and sizing of small pore defects using digital radiography and tracking”, EURASIP Journal on Advances in Signal Processing, 1-17, 2014.

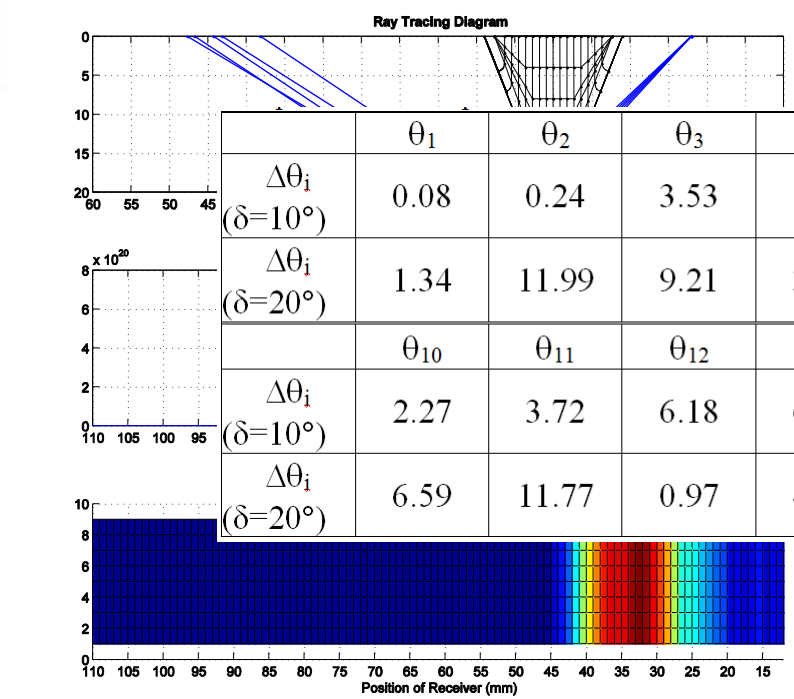


SCOD, a method to calculate the orientation of the dendrites in a weld based on UT data



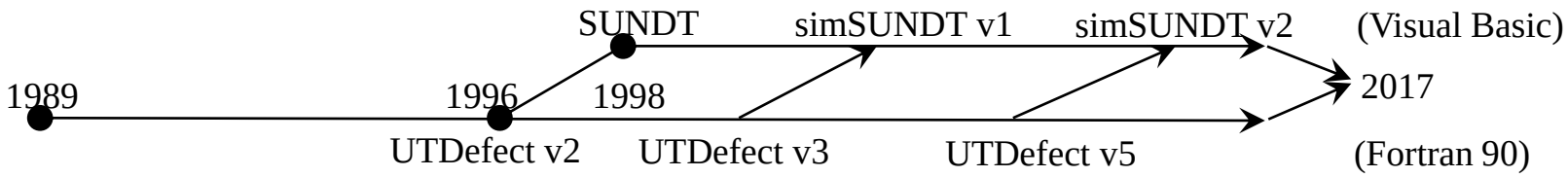


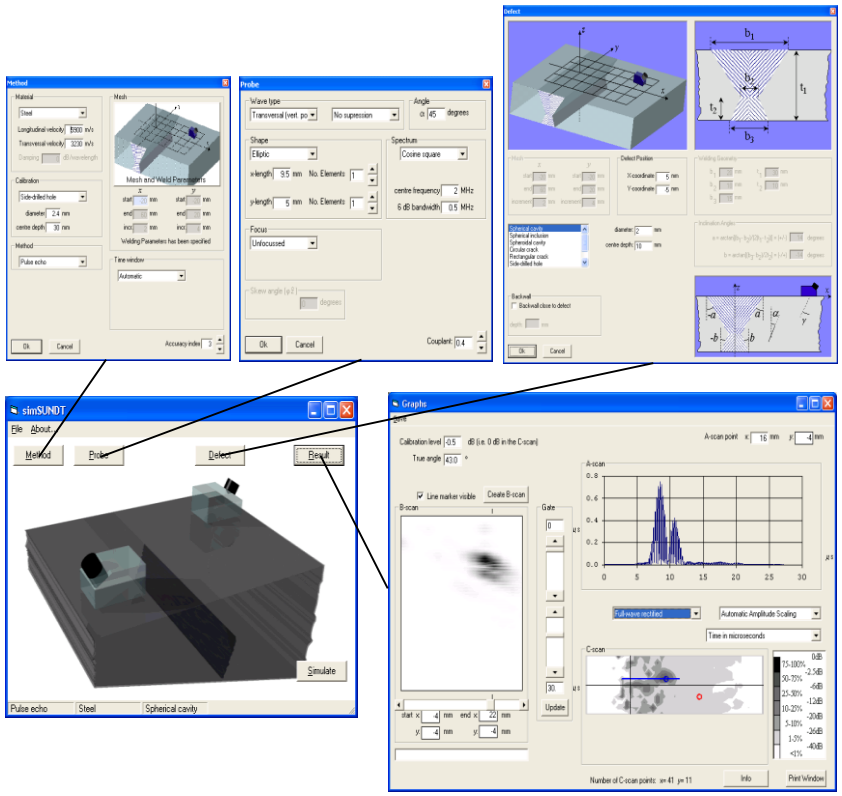




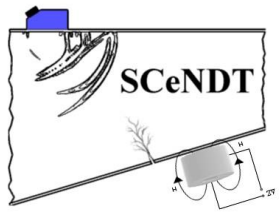
	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ_9
$\Delta\theta_i$ (δ=10°)	0.08	0.24	3.53	1.85	1.26	1.13	0.40	0.99	6.66
$\Delta\theta_i$ (δ=20°)	1.34	11.99	9.21	3.14	8.26	11.58	1.63	0.95	11.99
	θ_{10}	θ_{11}	θ_{12}	θ_{13}	θ_{14}	θ_{15}	θ_{16}	θ_{17}	
$\Delta\theta_i$ (δ=10°)	2.27	3.72	6.18	6.72	3.81	3.94	4.97	0.29	
$\Delta\theta_i$ (δ=20°)	6.59	11.77	0.97	4.17	8.63	4.64	5.38	0.48	

Development of Ultrasonic simulation tools (UTDefect/simSUNDT)



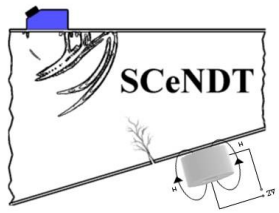


- **The simSUNDT program (freeware) consists of a Windows®-based pre-processor and postprocessor**
- **UTDefect used as a mathematical kernel**
- **Model of ultrasonic backscattering due to grain growth in a welded region**
- **The result can be read by a number of commercial analysis software**
- **Reduce number of test pieces and synthetic defects**



The *UT-01* procedure (manual UT)

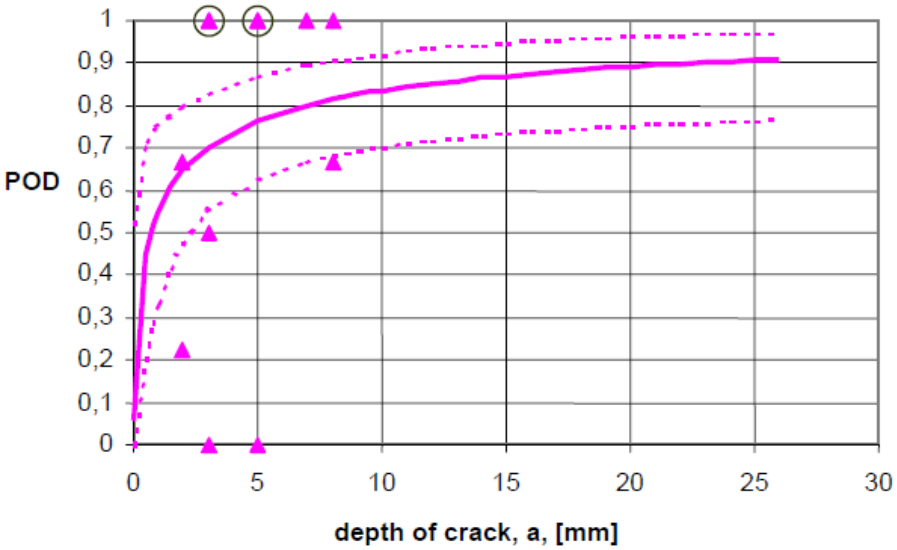
- The procedure was qualified (SQC) 1996 and UT personnel has been qualified according to it since (41 accepted between 1996 and 2004).
  - Includes specification of procedures for detection, sizing and characterization.
  - Incorporates both fatigue cracks and intergranular stress corrosion cracks (IGSCC).
  - The procedure specifies; components, defects, level of competence (personnel), method, equipment, calibration and inspection procedure.
- Data from qualifications of personnel was used 2005 to generate corresponding POD.
  - 97 implanted defects (mainly manufactured fatigue cracks).
  - 14 were real stress corrosion cracks withdrawn from nuclear plants and thereafter welded into the test pieces.



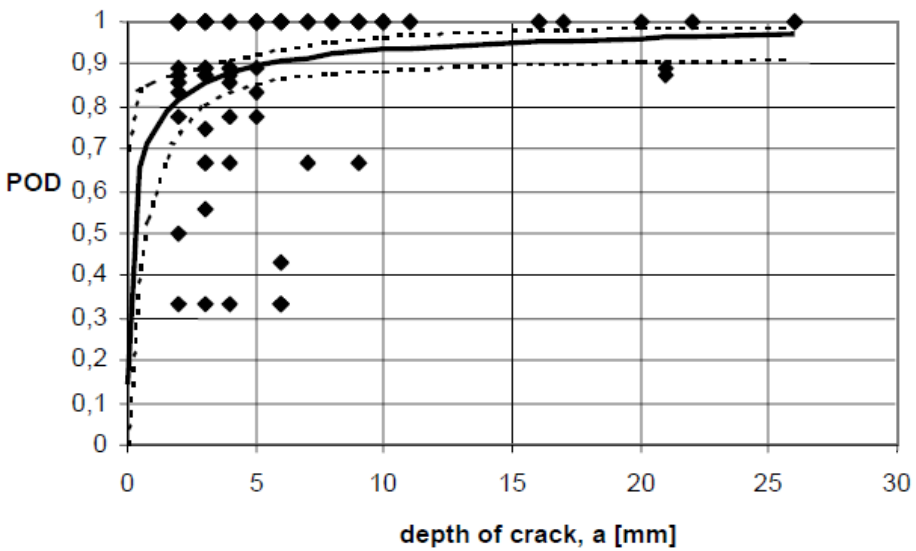
The *UT-01* procedure (manual UT)

From the reports "Probability of Detection for the Ultrasonic Technique according to the UT-01 Procedure"
(SKI 2005:03 by T. Jelinek, L. Tidström, B. Brickstad,)

- When only stress corrosion cracks (IGSCC) were considered:
  - POD = Φ(0.1218+0.3720·ln(a))

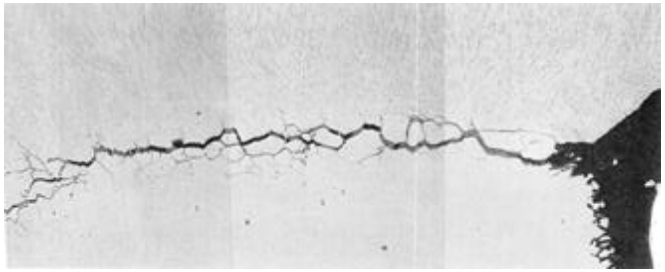


- When only fatigue cracks were considered:
  - POD = Φ(0.6503+0.3720·ln(a))

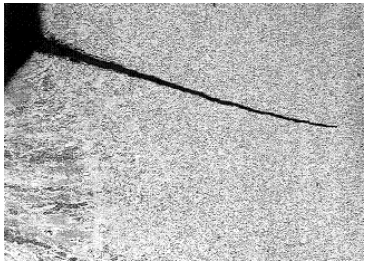


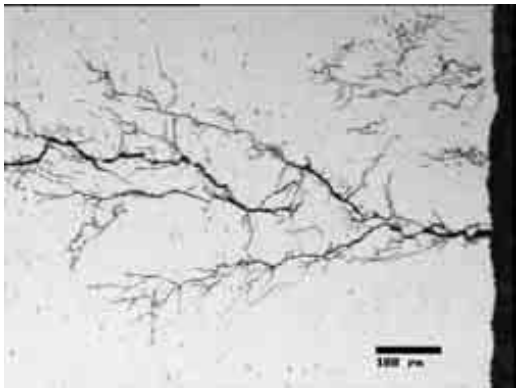
Examples of in-service induced cracks

Time dependant degradation (crack growth) :



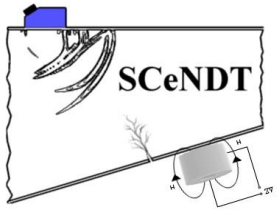
- ✓ Stress Corrosion Cracking
  - IGSCC
  - IDSCC
  - TGSCC



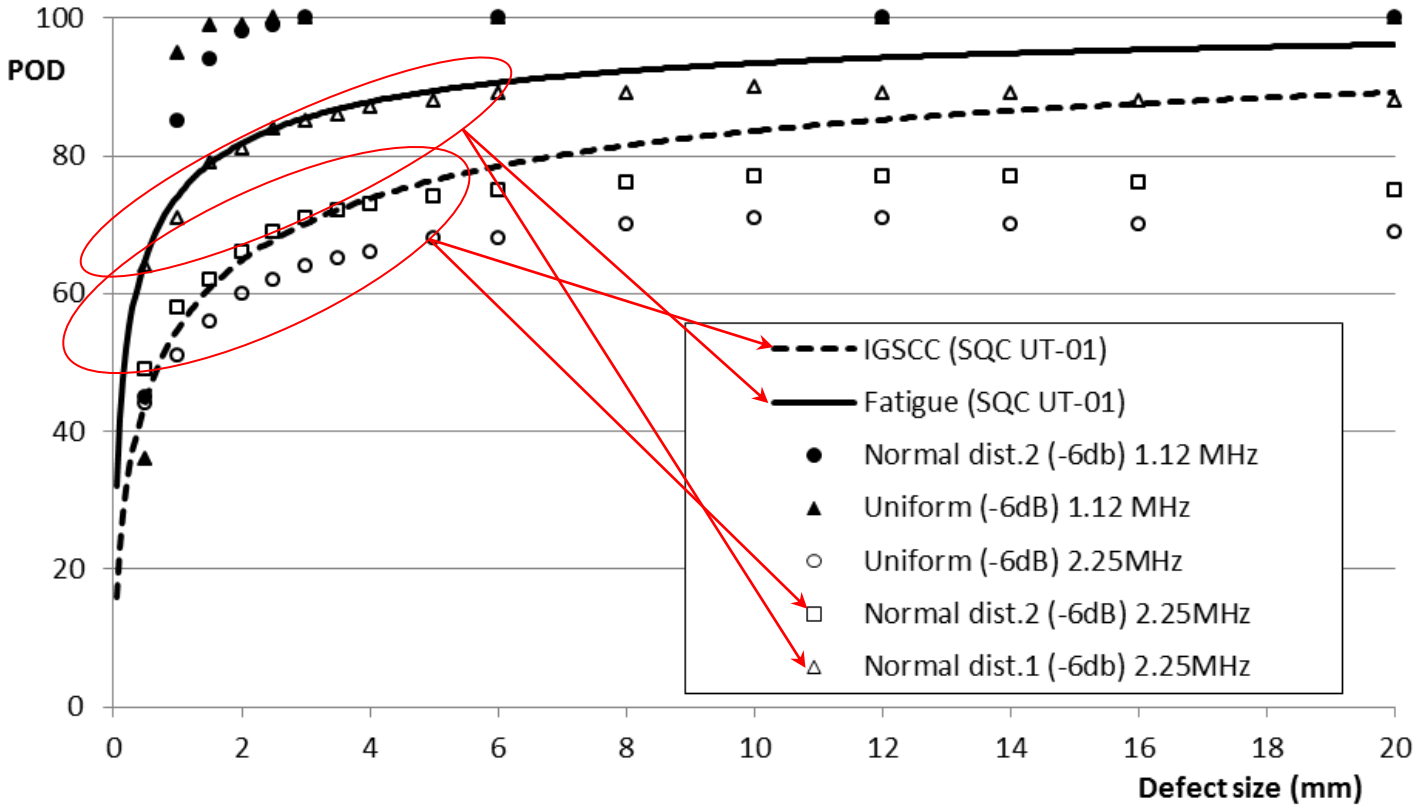


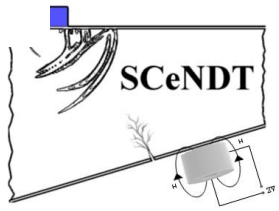
- ✓ Fatigue
  - Mechanical fatigue
  - Thermal fatigue

- ✓ Corrosion and erosion



Comparison with POD based on qualification results (1996-2005) according to SKI 2005:3

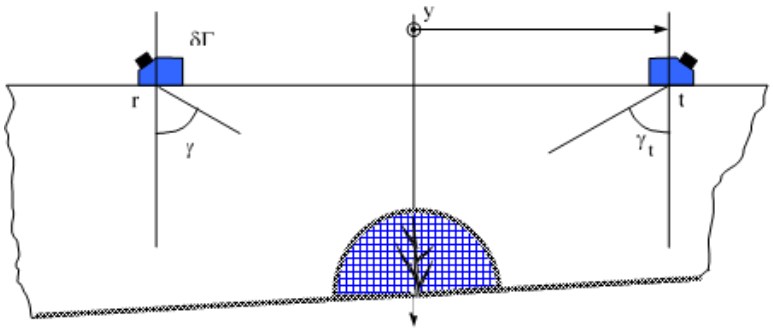




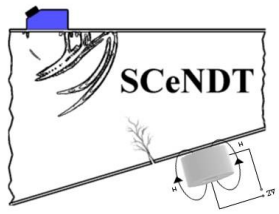
Ultrasonic probe modeling and Nondestructive Characterization of Stress Corrosion Cracks

170801-211231

- PhD (Maria Semenova)
  - A 2-D hybridmodel (FEM - T matrix)
  - A 3-D hybridmodel (FEM - T matrix)
  - Parametric study of branched cracks
  - Surface breaking 3-D hybridmodel

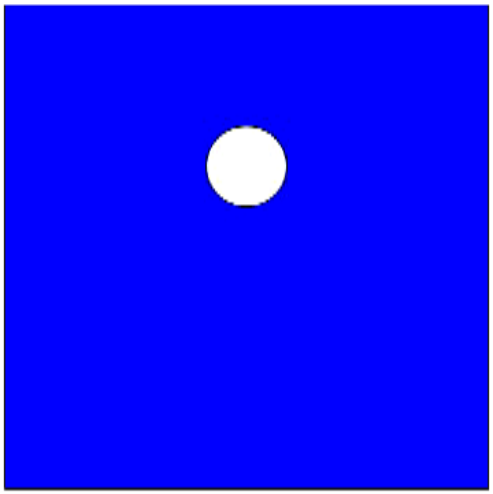


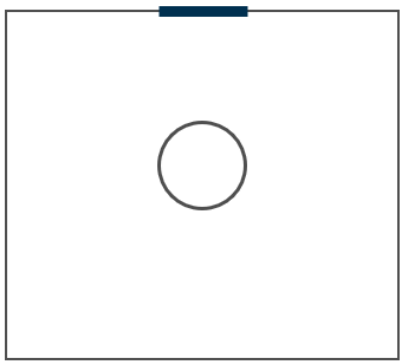
- Senior project
  - Develop a simplified model (parametric) of relevant SCC crack
  - Validation and benchmark (simSUNDT, CIVA and exp.): phased array probes and artificial defects
  - Implementation and experimental validation of developed hybrid model (CAD defined, produced by AM)



Comparison between three mathematical models of three well- defined ultrasonic NDT cases

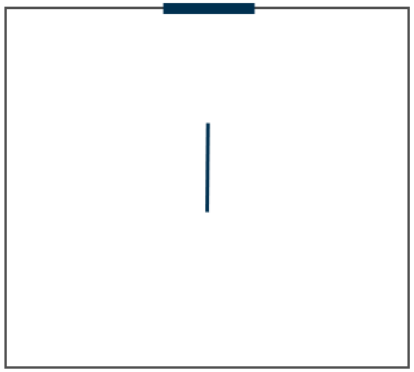
- Analytical model (UTDefect)
- Numerical models
  - k-Wave
    - Open source,
    - MATLAB and C++ toolbox
    - Complex and tissue-realistic media (medical)
    - Not to large density differences
  - COMSOL Multiphysics



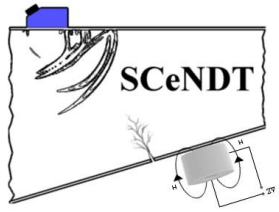


SDH

SC parallel

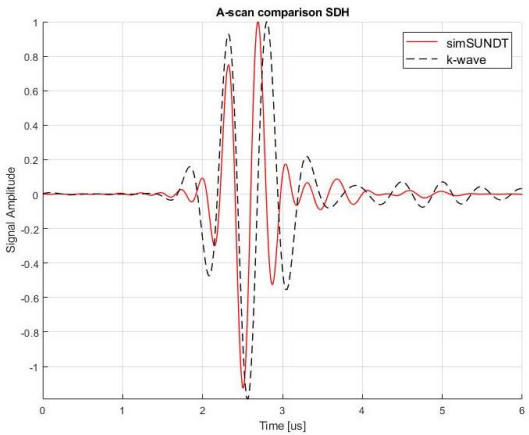


SC perpendicular

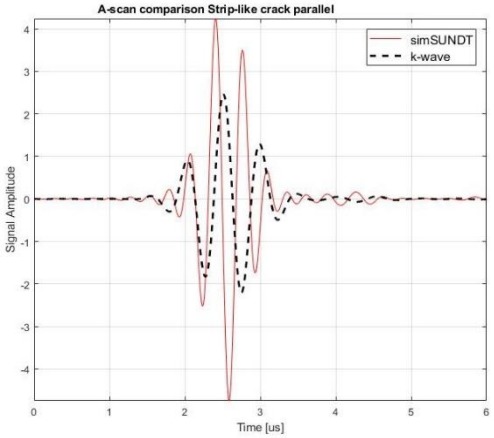


Results

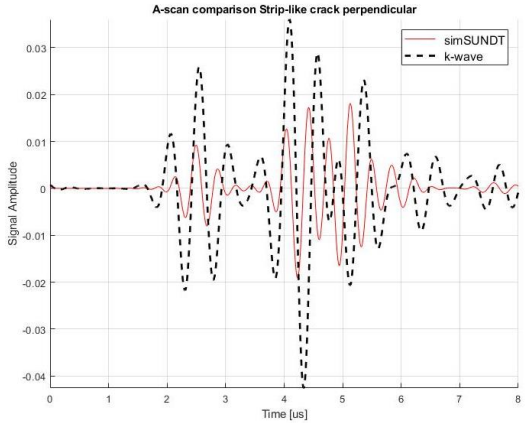
- A-scan comparison



SDH



SC parallel



SC perpendicular

- Position and shape of the signal are same and differences in values are less than 10 dB.
- There are some features in k-wave software, which may limit further use, e.g. the wavenumber depends on grid coordinates.