

Modellering av ultraljudsprovning i kärnkraftstillämpningar

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Innehåll

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- Användning av modellering
- Matematiska metoder vid modellering
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Varför forskning inom ultraljud?

- Leder till användbara resultat
- Ger teknologie doktorer inom området som kan jobba i branschen
- Kan hjälpa till att höja nivån och statusen på området
- Behövs för kvalificerad undervisning inom området
- Ett nytt mastersprogram inom "Nuclear engineering" startade på Chalmers hösten 2009

Användning av modellering

- Hjälper till att ge en fysikalisk förståelse, användbart som pedagogiskt hjälpmedel
- Enkelt att utföra parameterstudier, mycket billigare än experiment
- Bra för optimering av provning (sökartyp, etc) och utformning av testblock
- Kan användas vid kvalificering av metoder ("technical justification") och personal

Matematiska metoder vid modellering

- * Analytiska och halvanalytiska metoder för defekter i form av sfär eller sidoborrat hål samt för sökarmodellering
- * Numeriska metoder:
 - finita-element-metoder (FEM)
 - finita-volym-metoder (EFIT)
 - randintegralmetoder (BEM)
- * Högfrekvensapproximationer:
 - strålgångsmetoder
 - geometrisk diffraktionsteori (GTD) för kantspridning
 - Kirchhoffteori

Begränsningar med modellering

- Linjär teori
- Idealiserade geometrier, som plana ytor och skarpa sprickspetsar
- Inget brus såsom korngränsbrus
- Dämpning försummas eller modelleras mycket enkelt
- Homogena material antas
- Idealiserad sökarmodell, normalt pistongtyp

- Testblock har också sina begränsningar, framför allt vad gäller defekter

Datorprogrammet UTDefect (simSUNDT)

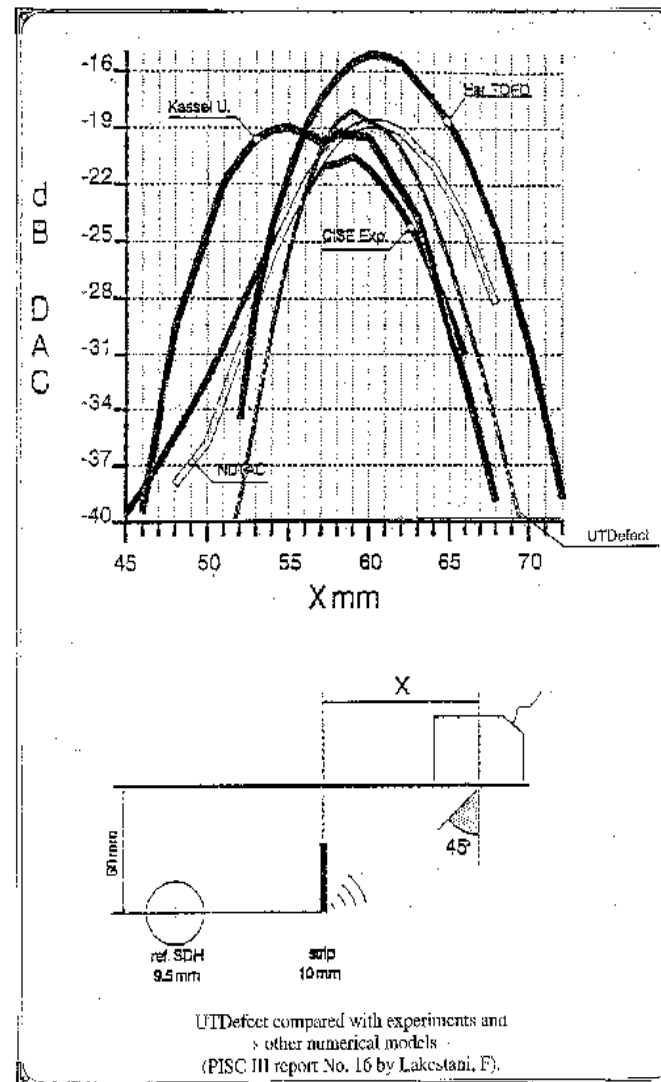
- Isotrop eller anisotrop (bara för vissa sprickor) komponent, plan scan-yta, lutande bak-yta
- Kontakt- eller immersionssökare av godtycklig typ, vinkel, frekvens, även fokuserad
- Defekter: sido-borrat hål, sfärer och sfäroider, cirkulär, rems-lik, och rektangulär spricka
- Data i form av A-, B-, C-scan, eller frekvensdata
- Sprickor i rörgeometrier har påbörjats

Valideringar

Jämförelser med experiment:

- Experiment och andra metoder i PISC III (Lakestani 1992)
- Experiment av AEA (Chapman 1995)
- Lutande sprickor (Becker et al. 1981)
- Riktiga utmattningssprickor (Eriksson et al. 1997)
- WFNDTC benchmarking (2004-9)

Jämförelser med PISC III



Jämförelse med PISC III

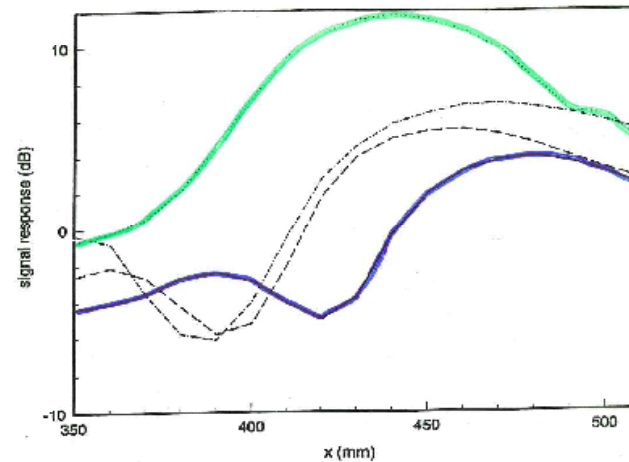
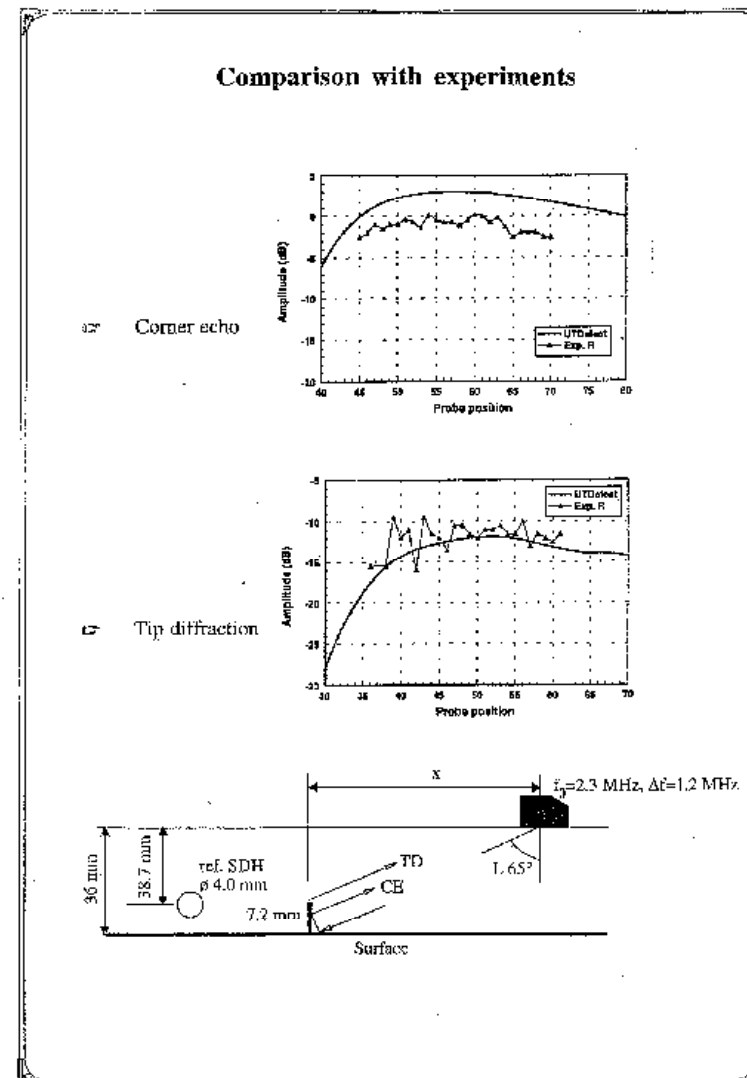


Fig. 12: Echo dynamic curve for a 10 mm strip-like crack tilted 15° away from the probe at centre depth 139 mm ; 70° SV probe. — UTDefect, experiments, - - - - NDTAC, - · - · - Kassel Univ.

Case	"True" angle	Peak response (dB)	Peak location (mm)	-6 dB width (mm)
experiment	-	11.8	438	111
Fig. 12	68.8°	4.0	480	110
$\gamma = 69^\circ$	67.7°	0.5	475	110
$\gamma = 71^\circ$	68.6°	6.9	485	110
$\gamma = 72^\circ$	70.0°	9.0	490	120
$\psi = 14^\circ$	68.8°	0.5	505	100
$\psi = 16^\circ$	68.8°	7.1	455	100
$\psi = 17^\circ$	68.8°	9.7	430	90
$\gamma = 72^\circ, \psi = 16.3^\circ$	70.0°	11.8	455	110

Table 2. Parametric study for Fig. 12. One (two in the last entry) parameter at a time is changed around centre frequency $f = 2.1$ MHz, bandwidth $\Delta f = 2.0$ MHz, nominal probe angle $\gamma = 70^\circ$, probe size $a \times b = 20 \times 22$ (in mm), crack tilt $\psi = 15^\circ$ and crack width $c = 10$ mm.

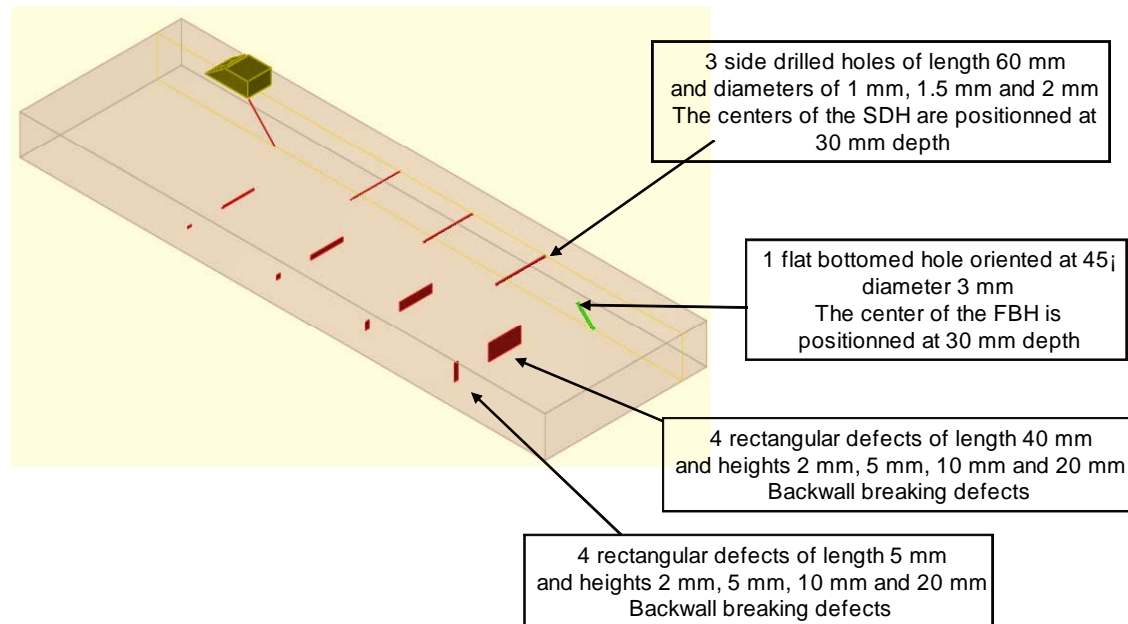
Jämförelse med riktiga utmattningssprickor



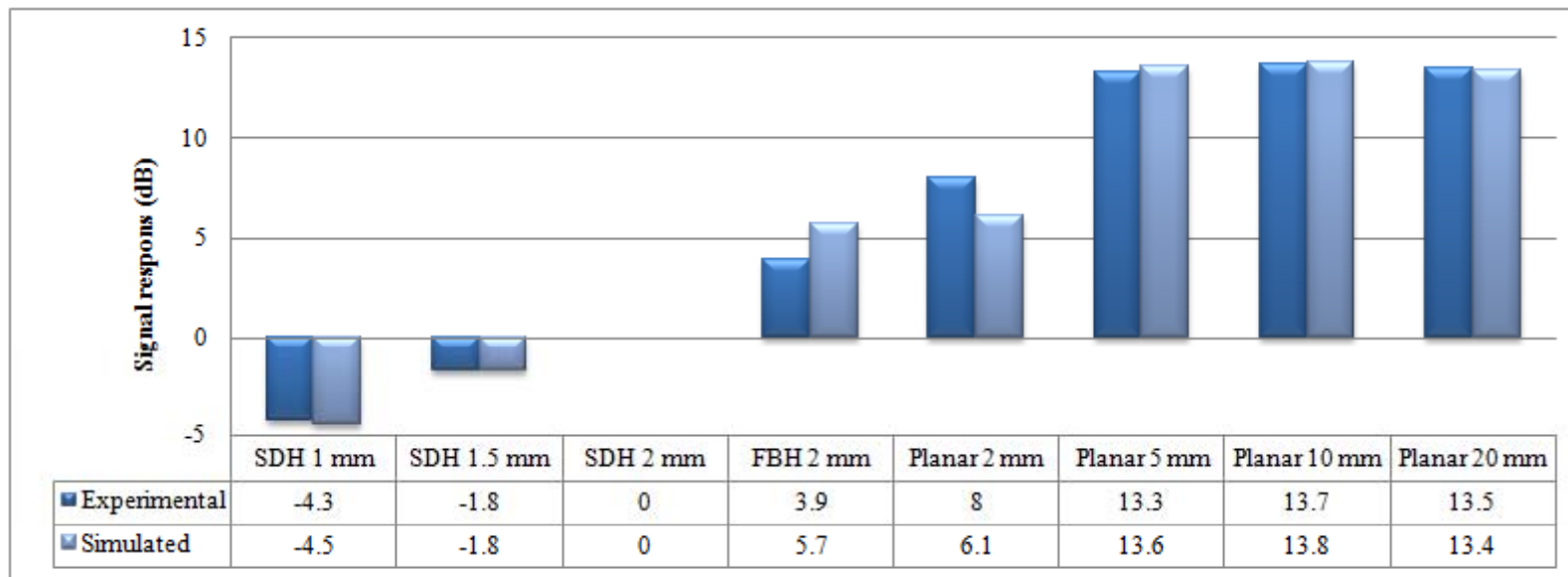
Benchmark WFNDTC 2009

Description of the configurations

Flaws



Benchmark WFNDTC 2009



The *UT-01* procedure (manual UT)

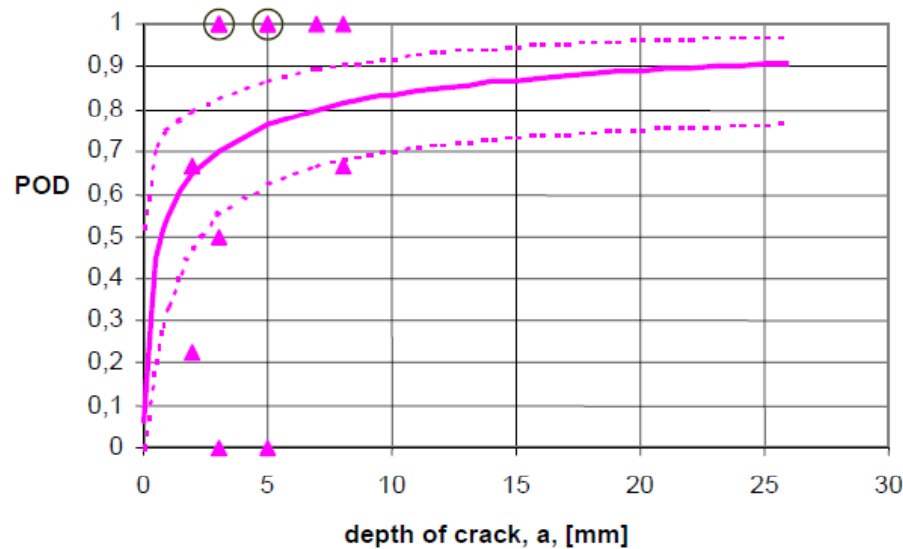
- The procedure was qualified (SQC) 1996 and UT personnel has been qualified according to it since (41 accepted between 1996 and 2004).
 - Includes specification of procedures for detection, sizing and characterization.
 - Incorporates both fatigue cracks and intergranular stress corrosion cracks (IGSCC).
 - 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,)

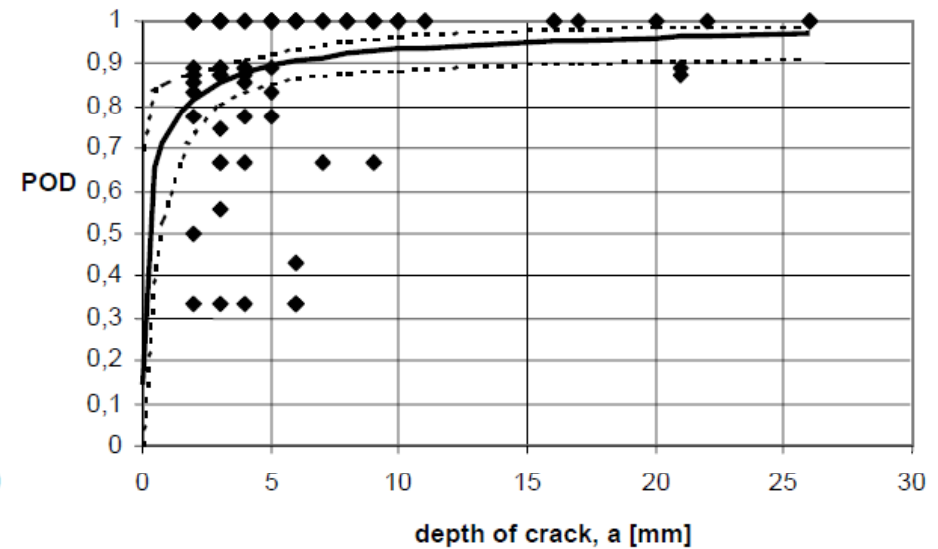
- When only stress corrosion cracks (IGSCC) were considered:

– $POD = \Phi(0.1218 + 0.3720 \cdot \ln(a))$



- When only fatigue cracks were considered:

– $POD = \Phi(0.6503 + 0.3720 \cdot \ln(a))$

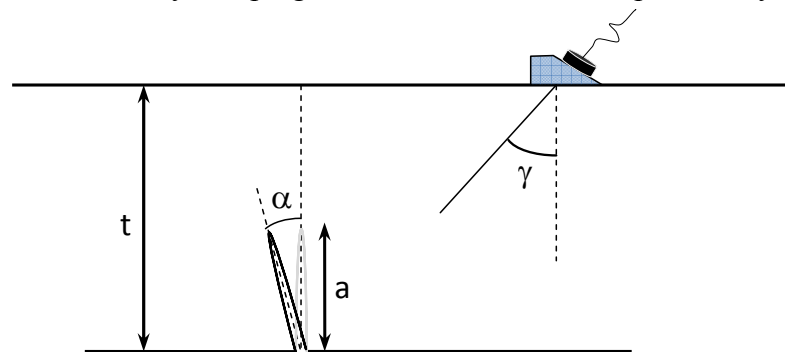


Identified essential parameter in *UT-01* that are included in simSUNDT

Set 1 parameters		
Defect size/width (a)	2-20 mm	
Object thickness (t)*	35-50 mm	
Defect tilt angle (α)	0° (perpendicular)	$\pm 15^\circ$
Defect skew angle	0°	$\pm 20^\circ$
Probe angle (γ)	45°	$\pm 2.5^\circ$
Effective area (circular)	Diameter 6.5 mm	$\pm 15\%$

Set 2 parameters	
Centre frequency	2.25 Mhz
Banwidth	44%
Couplant	0.4
Wave speed (C_L)	5720 m/s
Wave speed (C_S)	3120 m/s
Density	7950 kg/m ³

The DAC calibration in the procedure excludes thickness (t) as an essential parameter. The procedure also specifies compensation of losses caused by damping in the material which explains why this parameter is excluded

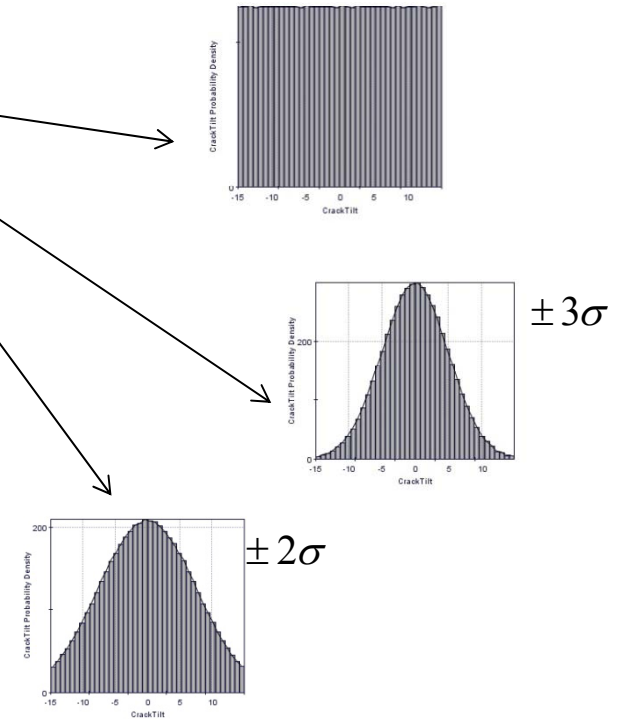


Procedure to generate synthetic based POD

- The stochastic simulation was made by using a Latin hypercube sampling (LHS) for creation of 5000 random designs for each data set, data according to:

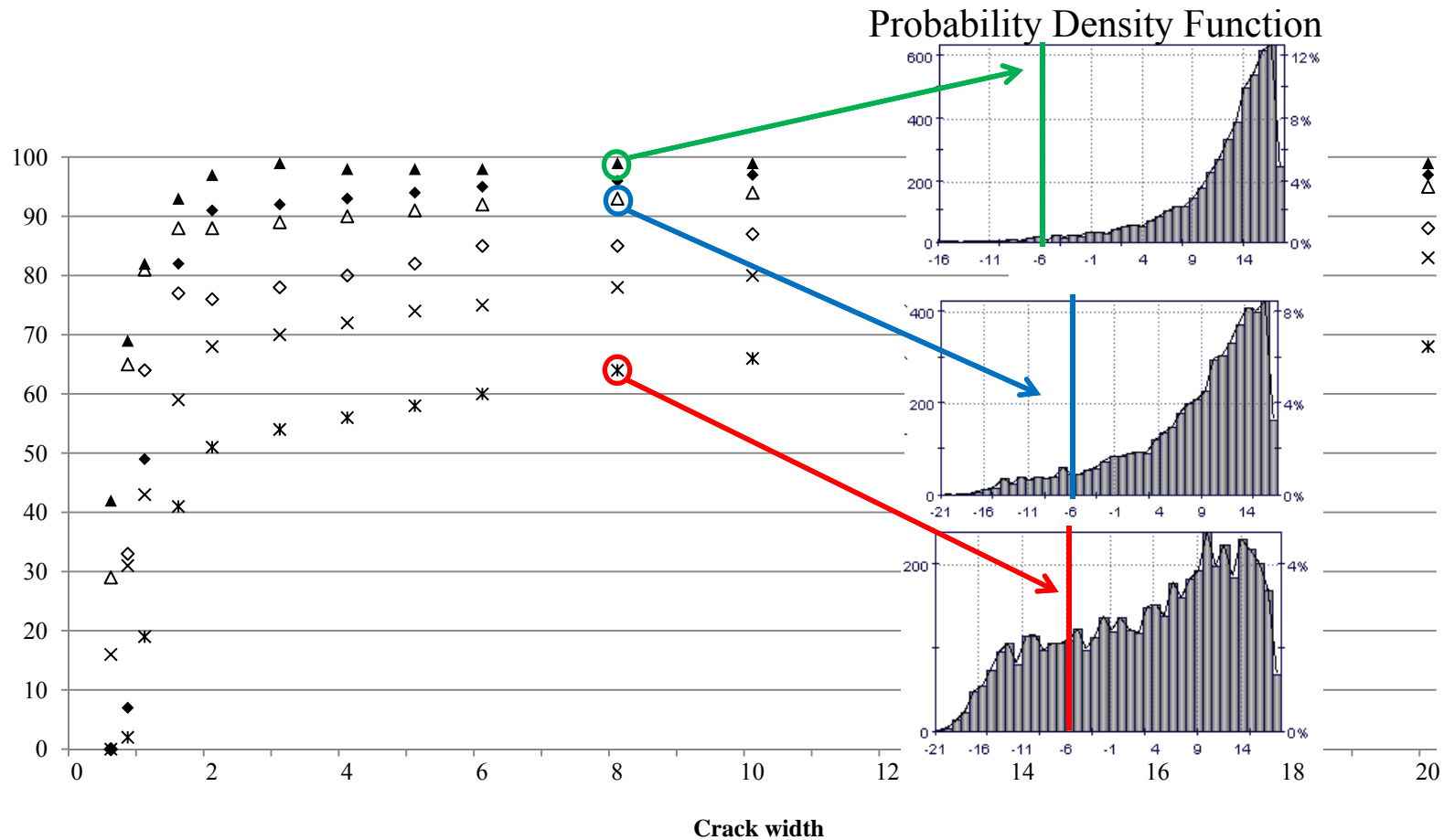
Stochastic distributed parameters	Distribution	Mean	Delta	SD
Defect tilt angle (α)	Uniform	0	15	
Defect tilt angle (α)	Normal 1	0		5
Defect tilt angle (α)	Normal 2	0		6.67
Defect skew angle	Uniform	0	20	
Defect skew angle	Normal 1	0		6.67
Defect skew angle	Normal 2	0		10
Probe angle (γ)*	Normal 1	45		0.8
Probe diameter	Normal 1	6.5		0.32

Probability Density Function

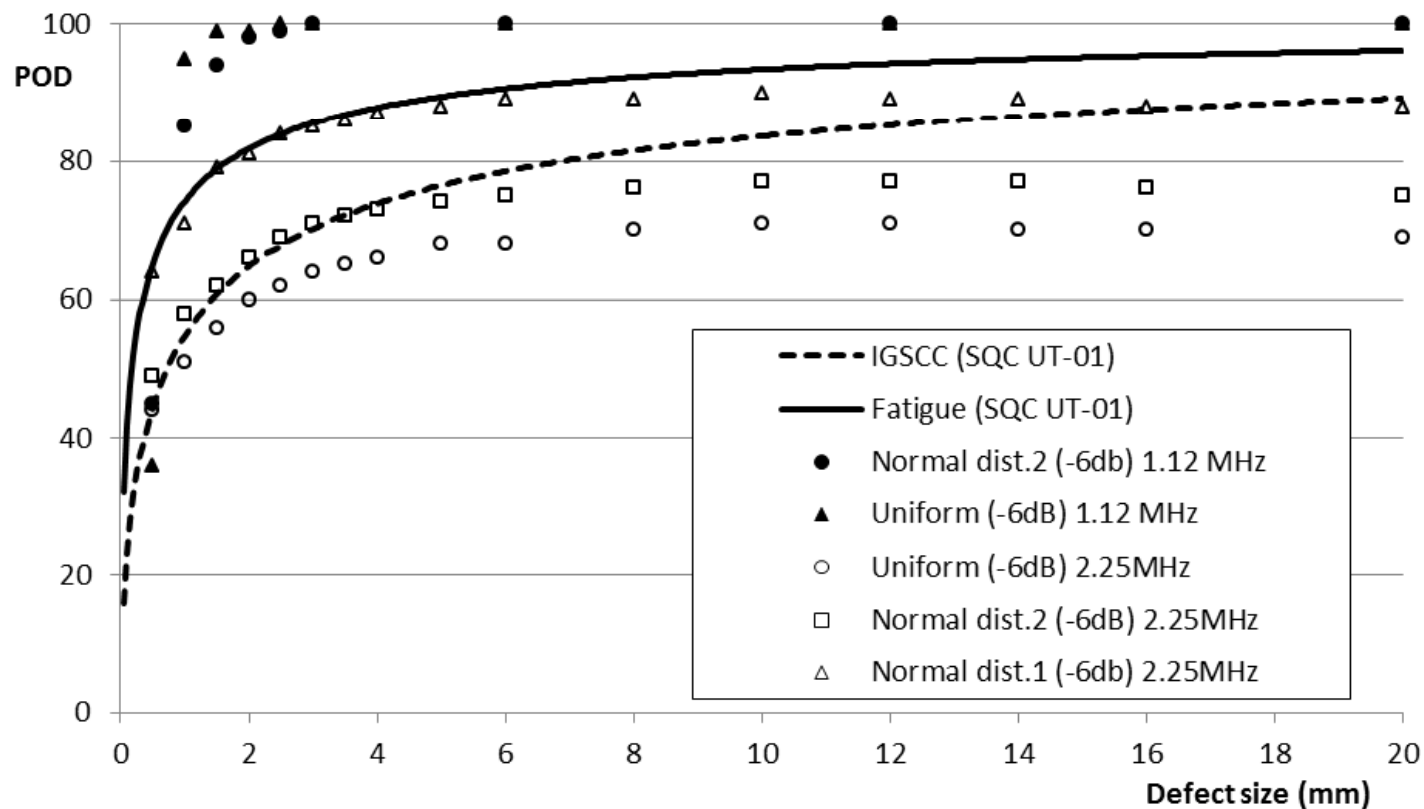


Procedure to generate synthetic based POD

The POD then is the percentage of 5000 that is above detection level (-6dB UT-01)

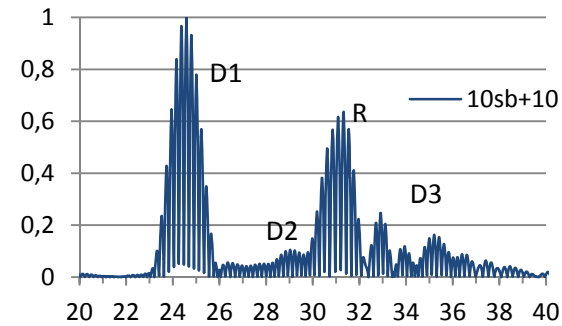
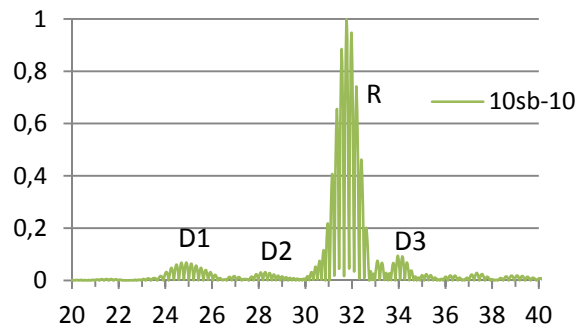
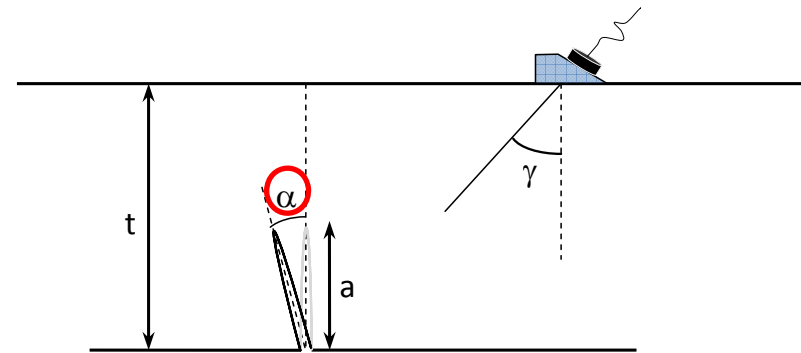
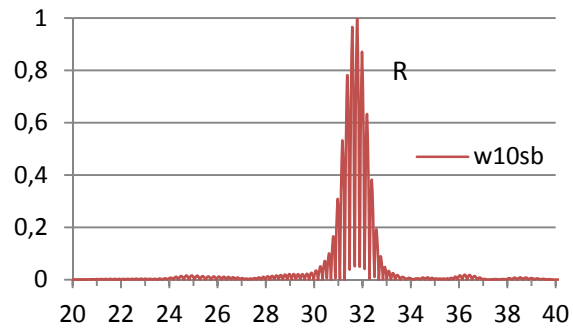


Comparison with POD based on qualification results (1996-2005) according to SKI 2005:3



Normalized time signal response

of cracks of width 10 mm according
tilt -10° , 0° and $+10^\circ$ respectively



Slutsatser

- Forskning inom området ger användbara resultat, lyfter kompetensen, etc
- Modellerings är användbart för parameterstudier, kvalificering, etc
- UTDefect är en bra modell med ett begränsat utbud av defekttyper
- UTDefect är hyggligt validerat, mer kan göras för pågående tillägg
- Utvidgningen mot icke-plana bak-ytor pågår

SCeNDT

Scientific Centre of NDT

Advanced NDT, Materials and Manufacturing Technology

- Håkan Wirdelius, director, theoretical mechanics, MM UT/MM DRT
- Gert Persson, ass. Prof., theoretical mechanics, MM UT/FEM
- Kenneth Hamberg, ass. Prof., material science, Material/NDT
- Peter Hammersberg, ass. Prof., material science, POD/MM DRT
- Lars Hammar, graduate student, DRT/ ET
- Anders Rosell, graduate student, MM ET (VAC)
- Lars Larsson, graduate student, MM ET
- Erik Lindgren, graduate student, DRT
- NN, graduate student, MM UT

Surface and microstructure engineering, MMT

- Lars Nyborg, Prof., material science, Material

Dynamics, Applied Mechanics

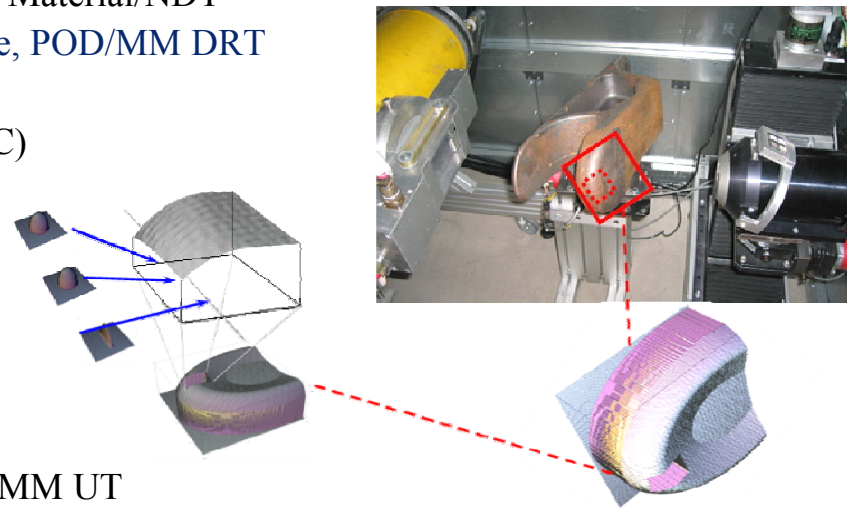
- Anders Boström, Prof., theoretical mechanics, MM UT
- Peter Bövik, ass. Prof., theoretical mechanics, MM UT/MM ET
- Per-Åke Jansson, ass. Prof., theoretical mechanics, MM UT

Imaging and Image Analysis, Signals and Systems

- Thomas Rylander, Computational Electromagnetics

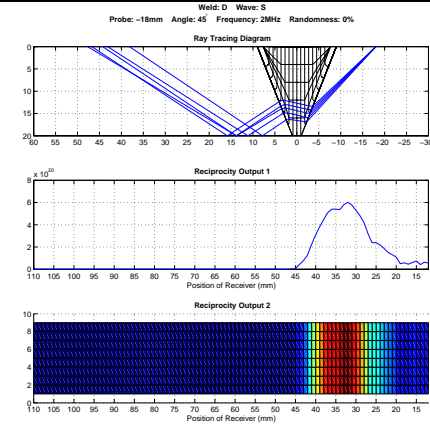
NDE group, Signals and Systems, UU (Ångström)

- Tadeusz Stepinski, Prof., measurement engineering, ET



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



Education

- ISI Technologies (graduate and PhD)
- Education for industry (graduate level)

The NDT laboratory

- High resolution X-ray technique (HiReX)

