List of Model-based POD Studies - MAPOD Working Group

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Model-Based POD Studies

- **Objective:**
  - **Develop a list of model-based POD studies that have been completed to date**
  - **Develop repository for results of review (with Irving Gray - NDE Technologies)**

Model-Based POD Studies

- **Potential Criteria:**
  1. **Description of NDE Measurement Model**
  2. Model Validation with Experimental Data
  3. **Simulated Studies of Model Parameter Variability on Measures:**
     - **flaw characteristics**
     - material properties, part geometry, measurement noise
  4. **Estimated POD / POFC - Based on Detection Criteria**
     - operator interpretation of signals / images
     - automated classification (threshold, â vs. a, advanced classifier)
  5. Validation of estimated POD / POFC through experimental studies
- **Categories:**
  - ***Limited* study (with potential for POD calculation)**
  - **Model-based POD study**
  - ***Validated* model-based POD study**

Model-Based POD Studies

- **Resources:**
  - **NTIAC Technology Assessment of POD for NDE** (Matzkanin and Yolken, 2001)
  - **Review Papers and Texts**
  - **Conference Proceedings**
    - **Review of Progress in QNDE**
    - **World Conference of NDT**
    - **European-American Workshops on Reliability**

List of Model-Based POD Studies

- **Early Works:**
  - **Fertig and Richardson (1983) – ultrasonic POD modeling**
  - **Martinez and Bahr (1984) - eddy current POD modeling**
- **SWRI (Beissner et al) and ISU (Nakagawa) - ET Works:**

#	Problem [Publication Year(s)]	Modality	Lead / Sponsors	Model (Validation?)	Simulated Factor Studies	POD / POFC Estimate (Validation?)
1	Surface breaking flaws [1988]	ET	Beissner et al. (SWRI)	BEM	- notch (length, depth) - scan spacing (wrt flaw) - experimental data used to construct no flaw pdf	- ROC curves of POD and POFA with varying flaw size (4 levels)
2	Surface breaking flaws [1990]	ET	Nakagawa et al (CNDE – ISU, SWRI)	BEM	- tight crack (length, depth) - scan spacing (wrt flaw) - experimental data used to construct noise pdf - convolve noise pdf with model generated pdf	- ROC curves of POD and POFA with varying flaw size (4 levels)

List of Model-Based POD Studies

- **ISU UT Works:**

#	Problem [Publication Year(s)]	Modality	Lead / Sponsors	Model (Validation?)	Simulated Factor Studies	POD / POFC Estimate (Validation?)
1	General [1989]	UT	Gray et al. (CNDE - ISU)	Kirchhoff	- planar circular cracks (radius, depth) - part geometry (fillet radius)	
2	Aircraft Engine Materials	UT	(CNDE – ISU) [FAA: ETC, phase I]	MOOT, Kirchhoff (FBH), Born (SHA)		- laboratory data
3	Aircraft Engine Billets (SHA)	UT	(CNDE – ISU) [FAA: ETC, phase I/II]	Born		- production system data
4	Riser Girth UT Welds	UT	(CNDE – ISU) [ARDAMA - Oil Industry]	SOV (Pores), Kirchhoff (FBH)		
5	Heat Exchanger Tube Cracks [1998]	UT	Sarkar et al, (CNDE – ISU)	Kirchhoff (FBH)	- deterministic model for known parameters (crack depth, inspection) - statistical model of noise (variable parameters)	- POD estimate - compare with experimental data (high variability due to flaw morphology)
6	Aircraft Engine Forgings	UT	(CNDE – ISU, PWA)	Kirchhoff (FBH)		- field data

List of Model-Based POD Studies

- **Lalita and Satish Udpa (ISU/MSU) ET Works:**

#	Problem [Publication Year(s)]	Modality	Lead / Sponsors	Model (Validation?)	Simulated Factor Studies	POD / POFC Estimate (Validation?)
1	Surface breaking cracks [1993]	ET	Rajesh et al. (ISU)	FEM	- notch (width, depth) - noise parameters: liftoff, surface roughness, temperature, material conductivity, measurement noise	- Monte Carlo simulation procedure - simulated POD – function of flaw width
2	Magnetostatic NDE [1994]	ET	Subramanya et al. (ISU)	FEM		
3	General [1994]	ET	El-Shafiey et al. (ISU)	FEM (3D, parallel)		
4	Pipeline inspection [1997]	ET	Zhang et al. (ISU)	FEM		
5	Cracks around fastener - MOI [2000-2004]	ET	Udpa et al (ISU/MSU)	FEM	- cracks - fastener holes	- POD / POFC estimate - operator interpretation

List of Model-Based POD Studies

- **UK National NDT Centre NNDTC (AEA Technologies, Harwell):**

#	Problem [Publication Year(s)]	Modality	Lead / Sponsors	Model (Validation?)	Simulated Factor Studies	POD / POFC Estimate (Validation?)
1	Subsurface cracks (planar defect) [1993]	UT	Ogilvy (UK NNDTC)	Kirchhoff, noise theory model (PODUT)	- flaw aspect ratio, orientation, depth, roughness - noise	- estimated POD / POFC
2	Surface cracks	UT	Silk (UK NNDTC)	Semi-empirical model (PODSURF)		
3	Cracks	UT	Temple (UK NNDTC)	TOFD, (PODTOFD)		
4	Ultrasonic C-scan model [1997-2000, 2002]	UT	Wall and Birch (UK NNDTC)	TOFD, (PODTOFD) [geometry convolved with UT beam, add noise]		- present multiple detection criteria (single point, multipoint, integral) - performed operator interpretation studies of simulated image data
5	Surface and near surface defects [1995]	ET	Holt (UK NNDTC)	FEM, POD model (PODET, OPERA)		
6	Ultrasonic C-scan model [1997-2000]	RT	Windsor and Wall (UK NNDTC)	Geometrical model (XPOSE)		

List of Model-Based POD Studies

- **Active Organizations - NDE Measurement Models (Study Model Parameter Variability):**
  - **CEA (CIVA)**
  - **IZFP (Spies et al)**
  - **Northwestern (Achenbach)**

#	Problem [Publication Year(s)]	Modality	Lead / Sponsors	Model (Validation?)	Simulated Factor Studies	POD / POFC Estimate (Validation?)
	Aircraft structures [2001]	UT	Aldrin et al. - (Northwestern) [SAIC, USAF]	BEM	- crack (length, location) - hole geometry	- validated model with experimental data - experimental POD validation of procedure - no model-based POD for comparison to date

List of Model-Based POD Studies

- **Additional Recent Works:**

#	Problem [Publication Year(s)]	Modality	Lead / Sponsors	Model (Validation?)	Simulated Factor Studies	POD / POFC Estimate (Validation?)
1	General [1998]	RT	Nockemann et al. (BAM – Germany)	Ray theory	- notch (depth) - noise	- compare theoretical and experimental POD results
2	Aircraft structures -SQUID NDE [1998]	ET	Ewing et al. (Vanderbilt University)	BIE		
3	General [2001]	UT	McNab et al (Strathclyde)	Ray theory NDT Workbench	- CAD model - coverage	
4	Piping - corrosion [2004]	UT (RT)	Volker et al. (TNO, Netherlands)	Kirchhoff, FDM (Ray theory)	- corrosion (depth, width)	- decision algorithm using simulated data - experimental validation

Model-Based POD Studies

- **Reason for List: Identify Existing Knowledge Base for MAPOD (Model Assisted POD)**
  - **Prior Work**
  - **Existing Models**
  - **Active Organizations**
- **Related Topics:**
  1. **NDE Model Benchmark / Validation Studies**
  2. **Inverse Methods in NDE**
  3. **Modeling Research and Development in NDE**

Related Topics

- **NDE Model Benchmark / Validation Studies**
  - **WFNDEC Benchmarking - UT:**
    - **CNDE-ISU,**
    - **IZFP – Germany (Spies),**
    - **Sungkyunkwan – S. Korea (Song)**
    - **IIT Madras – India**
  - **WFNDEC Benchmarking - ET (MFL, EC):**
    - **CNDE-ISU,**
    - **MSU,**
    - **U. Szczecin – Poland (Sikora et al.),**
    - **CII – Argentina (Pignotti et al.)**
    - **TU – Russia (Lunin et al.)**

Related Topics

- **Inverse Methods in NDE (Reviews)**
  - International Journal of Applied Electromagnetics and Mechanics (1997)
    - Bowler, J. R.
    - Kojima, F.
    - Banks, H. T., Smith, R. C., Zhang, Y.
    - Udpa, L., Udpa, S. S.
  - Auld, B. A., Moulder, J. C., Journal of NDE (1999)
- **Modeling Research and Development in NDE**
  - Reviews of NDE Modeling Research
    (Gray et al, Achenbach, Schmerr, Chimenti, Thompson, Lhemery, Spies)
  - Software (Measurement Model Examples):
    - EC: ECSIM (ISU), CIVA, OPERA 3D, VIC 3D
    - RT: XRSIM (ISU/NDET), CIVA
    - UT: UTSIM (ISU), CIVA, Imagine3D

Output from Review

- **Format Results into Database (Irving Gray)**
  - **Progress on Filling Database Categories from Review**

																							Flaw Morphology						
MAPOD-WG Key Code	MAPOD-WG Rating	Citation Title	Pub Source	Pub Year	Author	Location / Group	Industry	Sponsor	Problem	Material	Modality	Study Type	Model	V	Simulated Factor	POD	PFA / POFC	V	Method	Std Sample	Equipment	IC	Flaw Type	Flaw Size	Flaw Range	HF	Keywords	Abstract Link	Full Text (PDF)
				2002	Kupperman, D.S.	Argonne Nat Lab (ANL)	Nuclear	US NRC/ONRR	crack detection in SG tub	Inconel Alloy 6	EC	EX&Mod	Argone multiparameter al	good					RR	NRC Steam Generator Mockup							EC Array, POD, R		The link to
		PROBABILITY	RNE	2004	Zeng, Z., Xuan, L., Sun, L	MARG-E&EG ISU	Pipeline		parameter study for magnetic POD on pig		MT	EX&Mod	FEA & parametric functional mode	liftoff			PFA = 5%		Parametric Study				artificial flaw / notchs			not examined			
		INSPECTION (	ASIP 2003	2003	Herzog, P.G.	AF NDI Office Tinker AFE	Mil-AF	AF NDI Office	crack detection in Al plate	Al	JT-Phased Array	EXP	none	n/a	n/a					FastFOCUS R/D Tech UT Phased Array							UT Phased Array, not availab		Portion of A

- **Propose Formal Publication (Cover All MAPOD Effort)**
  - **Journal Publication: Special Issue**
  - **Textbook**