NDE Modeling and Simulation

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Modeling & Simulation

- Scope and benefits
- Present state
- Research directions
- MOU
- Schedule

Modeling

Mathematical description of physical phenomena; predict the outcome given certain input conditions.

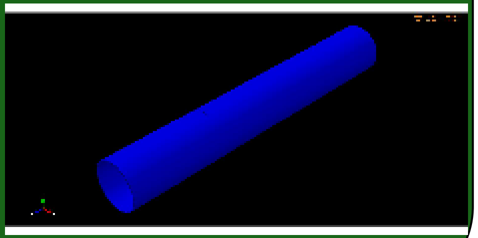
v = a*t

Models have validity domains that must be understood.

… but not at relativistic speeds.

Simulation

Using a model repetitively to perform a virtual experiment; in our case, an NDE system under specified conditions.



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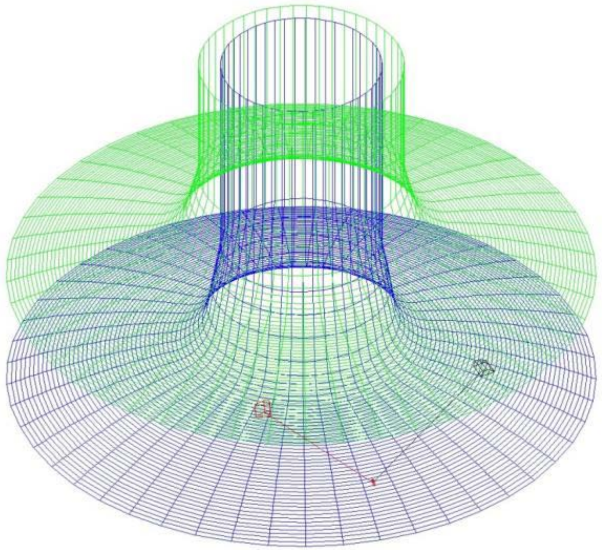
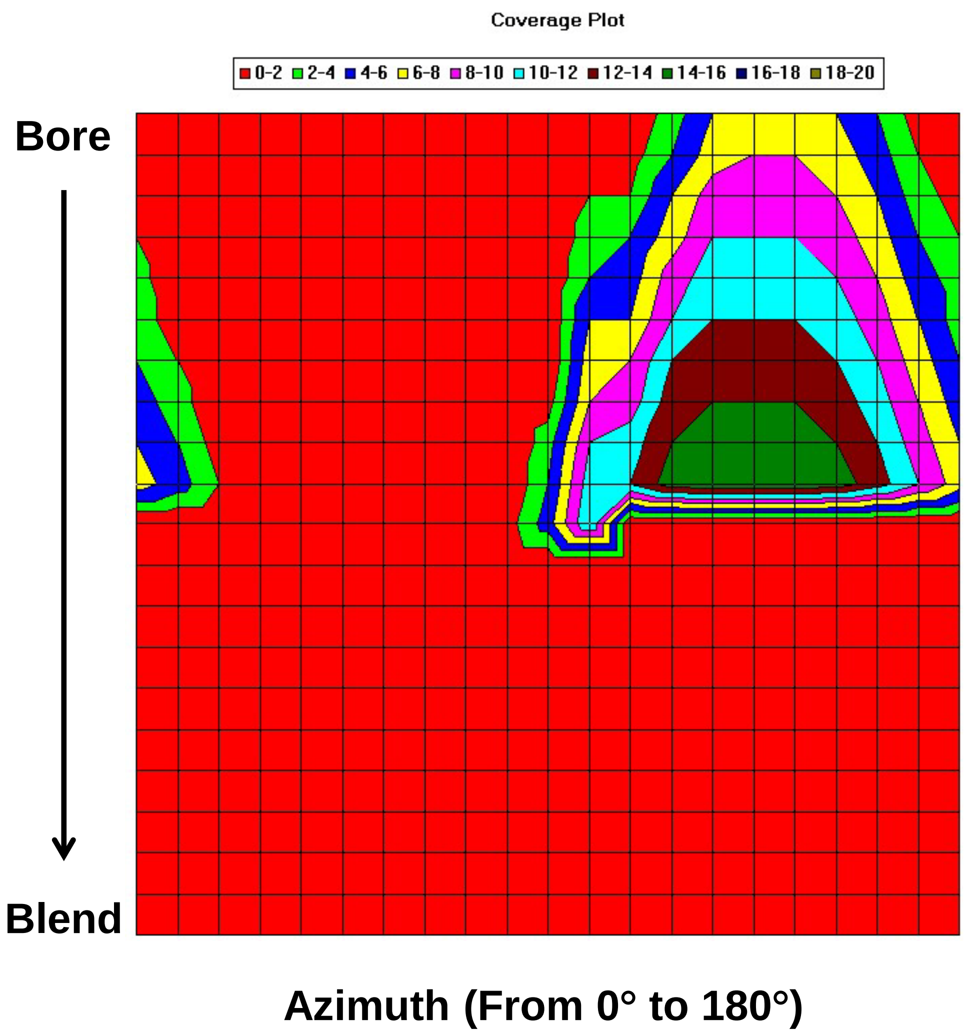
Scope

- Systematic application of physics/mathematics to predict the performance of NDE examinations (UT, ET, RT, etc.)
- This may include ray tracing geometry models, wave equation solutions, materials characterization, electromagnetic field, or basic data fitting
- Applications in EPRI's modeling research program
  - UT: similar and dissimilar metal piping welds; isotropic and anisotropic materials
  - ET: simple coils, complex coils, arrays
  - RT: powerful raytracing solutions
  - GW: guided wave examinations of underground piping; also plate materials such as tank walls and floors, fuel pool liners, containment liners

Mature models in use today

- **Nozzle UT models** in use since 1990s
- Calculates misorientation between the sound beam and the flaw, for all possible flaw locations
- Integral to qualifications



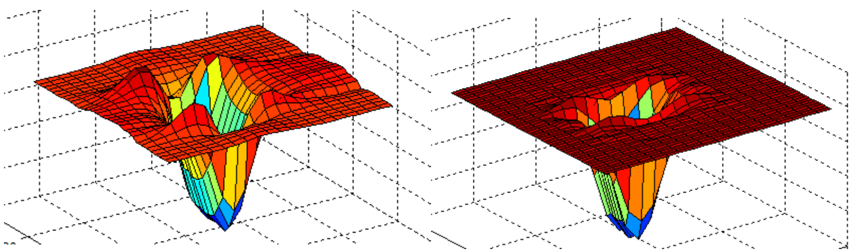


Mature models in use today

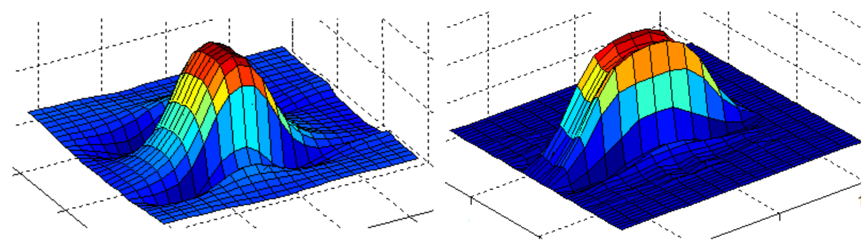
SGTSIM 4.0 for ET in steam generator tubing

Axial notch: Depth:100%TW, Length: 0.38”,Width: 0.005” (Tube ID 0.647”, OD 0.745”,300 kHz)

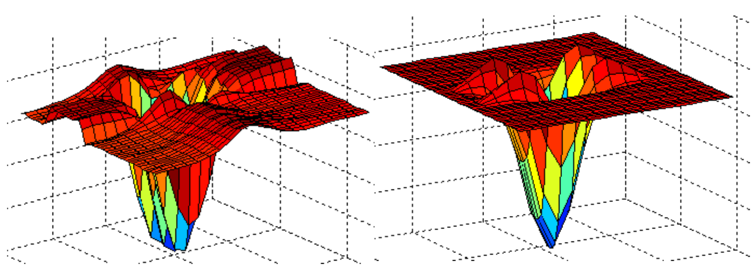
Horizontal

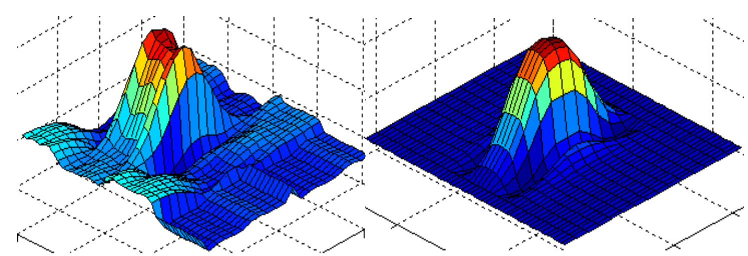


Vertical



Experiment | Simulation (fine mesh) | Experiment | Simulation (fine mesh)

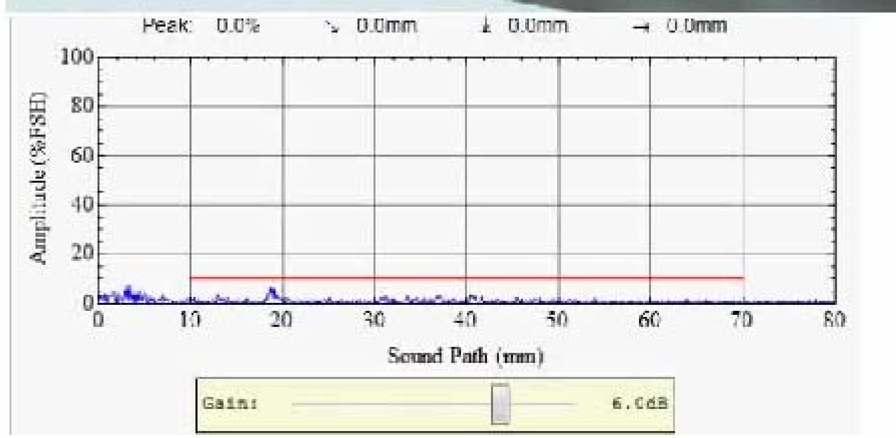




Axial notch: Depth:57% OD, Length: 0.38”,Width: 0.005” (Tube ID 0.647”, OD 0.745”,300 kHz)

Using modeling and simulation to support examiner proficiency – UT Simulator

- In development today
- PC-based
  - Examiner uses a mouse to scan
  - It's real data, from a recorded, encoded scan
  - Inexpensive plastic mockups can be used for scanning, or no mockup at all
- Uses UT recorded data file
  - From mockups
  - From the field
- Future state - create data files artificially, using models



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Potential applications for modeling

- Optimize procedures to improve reliability
- Prove the equivalency of techniques with different essential variables
- Extend the applicability of performance demonstrations
- Reduce the cost of developing reliability statistics

This requires stakeholder agreement on the models to use and their regimes of validity

Modeling is more efficient than physical experimentation and demonstration; it often leads to a better understanding of NDE capabilities

Memorandum of Understanding

- A Modeling and Simulation Attachment has been added to the MOU between EPRI and NRC RES
  - Signed April 2014
  - EPRI and RES are collaborating closely on a multi-year plan to reach agreement on model usage

ADDENDUM of MEMORANDUM OF UNDERSTANDING
between
U.S. NUCLEAR REGULATORY COMMISSION
and
ELECTRIC POWER RESEARCH INSTITUTE
on
COOPERATIVE NUCLEAR SAFETY RESEARCH

Memorandum of Understanding for Nondestructive Examination

Background

On March 14, 2007, the U.S. Nuclear Regulatory Commission (NRC) and the Electric Power Research Institute (EPRI) signed a Memorandum of Understanding (MOU) to allow and encourage cooperation in nuclear safety research that provides benefits for both NRC and industry. These benefits include technical information exchange and cost sharing, whenever such cooperation and cost sharing can be accomplished in a mutually beneficial manner. The

MOU contains four Tasks

- Benchmarking and validating models' regimes of validity
  - Task 1: Beamforming
  - Task 2: Wave modes
    - Bulk shear and longitudinal waves
    - Surface waves
    - Quasi-shear and quasi-longitudinal waves (anisotropic media)
  - Task 3: Flaw response
    - Specular, for detection
    - Diffractive, for sizing
- Mutually acceptable ways to use models
  - Task 4: Modeling best practices
    - Procedures for modeling that will produce results accepted by all parties

Containing the problem – there are many variables to select and prioritize

- Models to use
- Model functionalities
- Probe types
- Components to model
- Practical tasks

Prioritization of models

Model	Model priority	Model approach	Soundfields	Noise	Flaw response - specular	Flaw response - diffraction
CIVA	1	Semi-analytical; raytracing	Y	Y	Y	Y
Wave3000	2	Finite difference	Y		Y	Y
ABAQUS	2	Finite element	Y		Y	Y
Ultravision	2	Soundfields only	Y	N	N	N
Comsol	3	Finite element				
Matlab		Brute force				
PZFlex		Finite element				
Wave2000		Finite difference				

Prioritization of model functionalities and probe types

Functionality	Order of attack	Priority
Beamforming	1	1
Modes	1	1
Mode conversions	1	1
Specular	2	1
Diffraction (back)	3	3
Noise	4	2
Attenuation	4	2
Anisotropy	4	2
Diffraction (forward)	5	3
Immersion	6	4

Probe types	Order of attack	Probes priority
Conv. Single	1	1
Conv. Dual	2	1
PA linear single	3	1
PA linear dual	4	1
PA matrix single	5	3
PA matrix dual	5	3
TOFD	6	2
Total Focusing Method	7	4
Full Matrix Capture	7	4
Immersion		

Prioritization of components and usages

Component	Order of addressing	Component priority
Steel	1	
Stainless welds far side	2	2
DM welds	3	1
CRDM	4	
CASS	5	3
BMN	6	
HDPE	7	
Concrete	8	

Jobs	Jobs order of attack	Jobs priority
Probe and procedure design	1	1
Site-specific mockup process	1	1
Relief requests	2	2
Coverage	2	2
Proficiency maintenance	3	1
Qualification	3	3

Present status

- PNNL and EPRI are inventorying probes, mockups and encoded data sets
  - They need to be sufficiently documented for QA purposes
  - Maximize the use of existing data sets
  - Find the right minimum subset to support benchmarking and validation
- PNNL and EPRI are drafting procedures for performing and documenting the work to be performed within the MOU
  - Soundfield data acquisition
  - Flaw response data acquisition
  - Modeling
- EPRI is developing the QA plan

Summary

- Modeling and simulation have played a key role in NDE qualification for decades
- Today's better models and computing platforms will enable much more efficient design and qualification of NDE equipment and procedures
- Modeling and simulation are well suited for enhancing the ability of examiners to maintain their proficiency
- EPRI and RES are developing the framework under which modeling can be performed in a controlled and validated manner

Together…Shaping the Future of Electricity