SAND2008-3062C

Overview of Sandia Validation Challenge Workshop

Rich Field
Sandia National Laboratories
Albuquerque, NM 87185-0346
rvfield@sandia.gov

Organizers: K. Dowding, T. Paez, M. Pilch, J. Red-Horse (SNL)
R. Hills (NMSU), I. Babuska (Texas), R. Tempone (FSU)

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia Validation Challenge Workshop

- Held May 21 - 23, 2006 in Albuquerque
- Participants selected for their diverse perspectives
  - Communities: academia, professional committees, national laboratories, and industry
  - Backgrounds: various engineering disciplines, math / statistics
  - View points: Bayesian, engineering, frequentists, validation = calibration, validation = assessment
- Proceedings to appear in *Computer Methods in Applied Mechanics and Engineering,* Fall 2008
- More information:

  http://www.esc.sandia.gov/VCWwebsite/vcwhome.html

Sandia National Laboratories

Why Care About Validation?

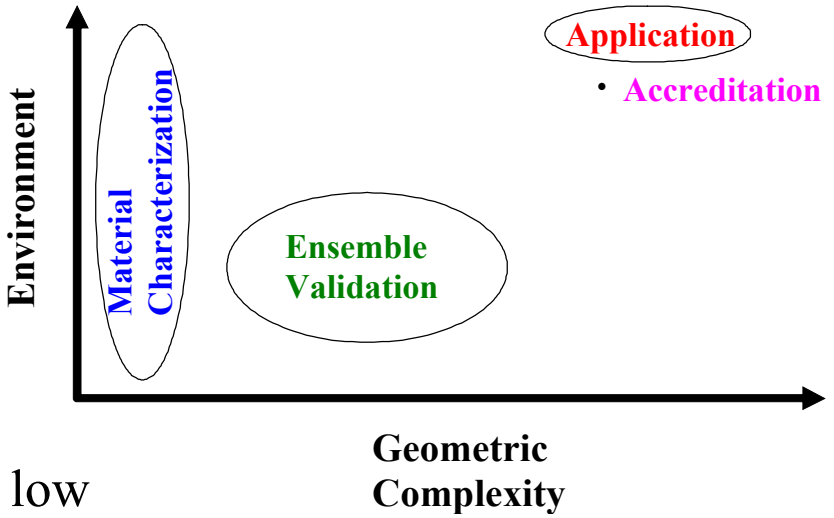
- Modeling and simulation is playing an increasing role in the design and in the assessment of regulatory compliance of high consequence systems
- Accurate quantification of margins and uncertainties in the decision context requires that:
  - Models accurately capture trends appropriate to the application parameter space
  - Sources of application-important variabilities can be reflected through the model
  - Uncertainties associated with the use of the model in the application parameter space can be quantified
- Model validation is a very necessary, but not sufficient, element in establishing the credibility of models for these important types of applications

Definition of Validation

- Validation: The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model
  - From AIAA, "Guide for the Verification and Validation of Computational Fluid Dynamics Simulations," (1998)

Intended Use
Validation is Application Specific

- **Regulatory Assessment (Application)** – Validation is best judged in the application context, which often involves a rigorous assessment against design or regulatory requirements
- **Accreditation** – subsystem or full-system testing with application hardware under conditions that more closely represent the application of the model
- **Ensemble Validation** – separate physics or low order interactions of important physics in stylized or de-featured geometries often for environments that are not fully representative of the application parameter space
- **Material Characterization** – identification of material properties or constitutive-law parameters



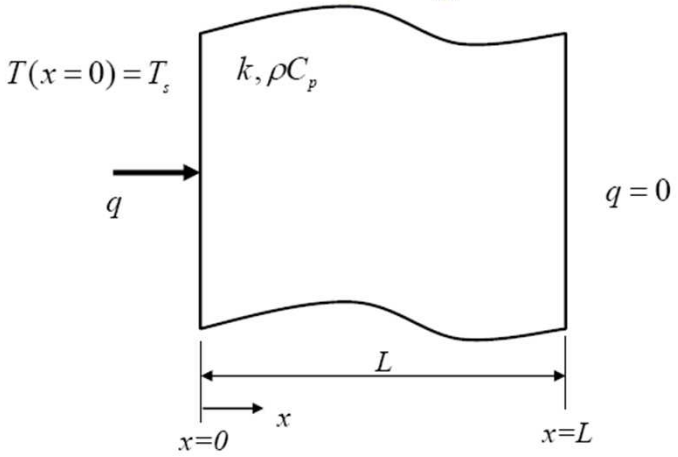
Sandia National Laboratories

Challenge Problems: Benchmarks for Methodology Comparison

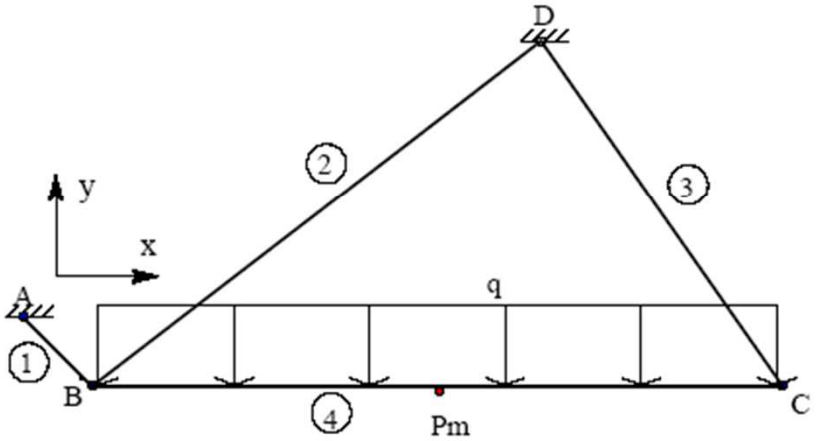
- Assessing accuracy and adequacy of a model when there is a database of multiple test
- Assessing accuracy and adequacy of a model when there is only a single test
- Assessing the impact of variabilities and uncertainties when using the model to extrapolate beyond existing databases
- Assessing confidence in regulatory assessments based on limited data and uncertainties in the use of the model

Three Challenge Problems

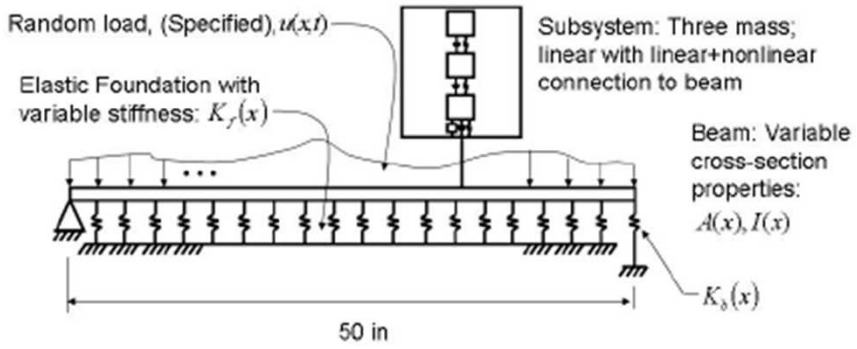
Thermal



Structural Static Frame



Structural Dynamics



- Three disciplines to engage broad interest and historical perspectives
- Hope is that methodology is independent of discipline

Sandia National Laboratories

Key Features Incorporated into Each Challenge Problem

- Provides an application context, requiring extrapolation of models beyond their validation basis, with a regulatory requirement stated in probabilistic terms
- Reflects hierarchal approach to validation: material characterization, validation against an ensemble of data, validation against a single test
- Easy to evaluate models that should not require subject matter expertise
- Synthetic "experimental data" generated from a truth model acting as a surrogate for Mother Nature

"Truth Model(s)" never to be revealed!!

Key Features NOT Incorporated into Each Challenge Problem

- Diagnostic variability and uncertainty (measurement errors) were not added
  - Over-simplification of real-world experimental conditions
- Numerical errors need not be addressed
  - Simple, easy-to-evaluate models can be assumed to be free of numerical errors
  - Many real world applications may require the use of under-resolved models
- Nonlinear coupled multi-physics
  - Nonlinear coupled multi-physics is common in many real world applications
  - May require validation against SRQs that are different from what the application demands

Today's Schedule

- AM Session: Thermal Problem
  1. *Formulation of the Thermal Problem* by Dowding, Hills
  2. *Thermal Problem Solution Using a Surrogate Model Clustering Technique* by Brandyberry
  3. *A Bayesian Analysis of the Thermal Challenge Problem* by Berger
  4. *Summary of the Approaches Applied to Solve the Thermal Problem* by Hills & Dowding
- PM Session: Structural Dynamics Problem
  1. *Sandia Validation Methods Workshop: Structural Dynamics Problem Definition* by Red-Horse & Paez
  2. *A Top-Down Approach to Calibration, Validation, Uncertainty Quantification and Predictive Accuracy Assessment* by Hasselman & Lloyd
  3. *NASA Langley's Approach to the Sandia Structural Dynamics Challenge Problem* by Horta, Kenny, Crespo, Elliot
  4. *A Probabilistic Approach to the Validation Problem* by Ghanem, Red-Horse, Doostan
  5. *Error and Variability Characterization in Structural Dynamics Modeling* by McFarland & Mahadevan

Workshop Proceedings (1 of 2)

Special Issue of *Computer Methods in Applied Mechanics and Engineering*, (Hughes, Oden, and Papadrakakis Editors), will appear Fall, 2008

- *Workshop Overview, Problem Definitions, and Summary*
  - Richard G. Hills, Martin Pilch, Kevin J. Dowding, John Red-Horse, Thomas L. Paez, Ivo Babuska, and Raul Tempone. "Validation Challenge Workshop"
  - Ivo Babuska, Fabio Nobile, and Raul Tempone. "Formulation of the Static Frame Problem"
  - Dowding, K. J., M. Pilch, R. G. Hills, "Formulation of the Thermal Problem"
  - Red-Horse, J. R., Paez, T. L., "Sandia National Laboratories Validation Workshop: Structural Dynamics Application"
  - Ivo Babuska and Raul Tempone. "Static Frame Challenge Problem: Summary"
  - R. G. Hills, Dowding, K. J., and L. Swiler, "Thermal Challenge Problem: Summary"
  - Paez, T. L., Red-Horse, J. R., "Structural Dynamics Challenge Problem: Summary"
  - Kevin J. Dowding, Ivo Babuska, Richard G. Hills, John Red-Horse, Thomas L. Paez, and Raul Tempone. "Validation Challenge Workshop Summary"
- *Static Frame Problem*
  - Ivo Babuska, Fabio Nobile, and Raul Tempone, "Model Validation Challenge Problem: Static Frame Problem. Sandia Validation Workshop"
  - Jan Chleboun, "An approach to the Sandia Workshop Static Frame Challenge Problem: A Combination of Elementary Probabilistic, Fuzzy Set, and Worst Scenario Tools"
  - M.D. Grigoriu and R.V. Field Jr, "A Solution to the Static Frame Validation Challenge Problem Using Bayesian Model Selection"
  - Pradlwarter H. J. and G. I. Schueller, "The Use of Kernel Densities and Confidence Intervals to Cope With Insufficient Data in Validation Experiments"
  - Ramesh Rebba and John Cafeo, "Probabilistic Analysis of a Static Frame Model"

Workshop Proceedings (2 of 2)

- *Thermal Problem*
  - Brandyberry, M. D. "Thermal Problem Solution Using a Surrogate Model Clustering Technique"
  - Ferson, S., W. L. Oberkampf, and L. Ginzburg. "Model Validation and Predictive Capability for the Thermal Challenge Problem"
  - Higdon, D., C. Nakhleh, J. Gattiker, B. Williams. "A Bayesian Calibration Approach to the Thermal Problem"
  - Hills, R. G. and K. J. Dowding. "Multivariate Approach to the Thermal Challenge Problem"
  - Liu, F., M. J. Bayarri, J. Berger, R. Paulo, and J. Sacks. "A Bayesian Analysis of the Thermal Challenge Problem"
  - McFarland, J and S. Mahadevan. "Multivariate Significance Testing and Model Calibration under Uncertainty"
  - B. M. Rutherford. "Computational Modeling Issues and Methods for the "Regulatory Problem" in Engineering – Solution to the Thermal Problem"
- *Dynamics Problem*
  - Ghanem, R. G., Doostan, A., Red-Horse, J., (2008), "A Probabilistic Construction of Model Validation"
  - Hasselman, T., Lloyd, G., (2008), "A Top-down Approach to Calibration, Validation, Uncertainty Quantification and Predictive Accuracy Assessment"
  - Horta, L. G., Kenny, S. P., Crespo, L. G., Elliot, K. B., (2007), "NASA Langley's Approach to the Sandia Structural Dynamics Challenge Problem"
  - McFarland, J., Mahadevan, S., (2008), "Error and Variability Characterization in Structural Dynamics Modeling"
  - Rutherford, B. M., (2008), "Computational Modeling Issues and Methods for the 'Regulatory Problem' in Engineering – Solutions to the Structural Dynamics and Static Frame Problems"
  - Zang, C., Schwingshackl, C. W., Ewins, D. J., (2008), "Model Validation for Structural Dynamic Analysis: An Approach to the Sandia Structural Dynamics Challenge Problem"

Items presented at EM08

Sandia National Laboratories