Advanced Design for Complex Systems (1. Introduction)

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Course Info

- Professor: Choi, Hae-Jin,
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- Class:
  - Wed (3-6 pm), 302(Graduate hall)-302

- Text books:
  - Related papers (handouts or email distribution)

- Assessment:
  - Continuous assessment (10%), mid-term (50%), class project (40%)

- Office hour: Email appointment
Characteristics of Complex Systems

- **Uncertainty**
  - Natural uncertainty (variability)
  - Model parameter uncertainty
  - Model structure uncertainty

- **Complex structures**
  - Hierarchy
  - Multiple scales
  - Multidisciplinary, Multiple performances

- **High performance**
  - Extreme/uncertain condition

- **Long lifecycle time**
  - Long development time
Mission: Design of Multifunctional Energetic/Structural Materials (MESMs)
Tailoring material structure and processing paths to achieve properties and performance levels that are customized for a particular application…..

(Seepersad et al., 2004)
**MESM Multiscale Simulation Models**

**Multiscale Design Variables**
- **Material:** Constituents; Sizes and Volume Fractions of Particles; Spatial statistics

**Atomic-level Model**
- [Lu, Wu, Patsamatla]

**Continuous Level Model**
- Multifunctional Characteristics
- Dynamic Strength
- Reaction initiation: density of reaction initiation sites and associated probability

**Discrete Particle Mixture Model**
- [Austin]

**Micro-level Model**
- EOS* = Equation of State

**System Level Model**

**Reaction Initiation Temperature**
- (fn. of Material parameters)
Linear Cellular Alloy Heat Exchanger

**Step One**
Paste Preparation

- Oxide Powders
- H₂O
- Additives

**Step Two**
Shape Fabrication

- Honeycomb Extrusion

**Step Three**
Direct Reduction

- Drying
- H₂

**Finished Metal Part**

**Flexible Die Design**

**Courtesy of Lightweight Structures Group, Georgia Tech**
Challenge: Random Cell Wall Failure

- Random error of heat transfer rate under random cell wall failure

Unparameterizable Variability
Radial Disk Resonator based Biosensor

- Frequency: up to 56 MHz
- Q Factor: 8,000 at 20 MHz
- Mass sensitivity: 60-220 µm²/ng
Strategic Product Design

Product design with accurate prediction of future customer requirements

Long lifecycle of complex systems
Blast Resistance Panel (Sandwich)

- Multiobjective design goals
  - Maximum energy absorption
  - Lightweight
  - Robust to uncertainty in impulse loading

- 3 stage of deformation theory (Fleck and Deshpande)
- Shear off constraints (Xue and Hutchinson)
- Spherical loading blast model
- Cambridge ANN materials models

Syllabus

- Introduction to complex engineering systems design methodology. (1 week)
  - Factors that contribute to complexity: multiple objectives, uncertainty, multiple disciplines, multiple scales, concurrency.
  - Examples of complex engineering systems.

- Design of experiments and metamodelling. (3 weeks)
  - Alternative experimental designs, including factorial, fractional factorial, and Latin Hypercube designs.
  - Metamodelling methods, including response surfaces and kriging.
  - Applications of designed experiments and approximate models for design space exploration.
  - Design and manufacturing in decentralized environments.
Syllabus

- Multiobjective decision-making (2 weeks)
  - Pareto sets and trade-offs.
  - Basic multiobjective formulations: weighted sum, compromise programming, etc.
  - Utility theory. Game theory.
  - Satisficing methods and goal programming.

- Decision-making under uncertainty (2 weeks)
  - Sources of uncertainty. Representation of uncertainty.
  - Propagation and estimation of uncertainty. Robust design principles and methods.
  - Design flexibility with robust design methods.
Syllabus

- Multiscale design methods (2 weeks)
  - Overview of multidisciplinary and multiscale design problem formulations. Issues of coupling, decomposition, and collaboration.
  - Robust design for multidisciplinary applications.

- Design for market systems (1 weeks)
  - Product platform and family design
  - Strategic product design

- Seminar with individual projects (3 weeks)