THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

CHE384, From Data to Decisions: Measurement, Uncertainty, Analysis, and Modeling

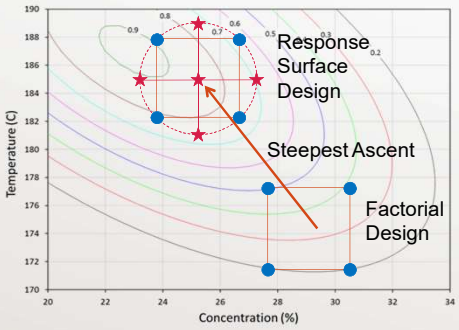
Lecture 72 Final Thoughts on Design of Experiments

Chris A. Mack

Adjunct Associate Professor

http://www.lithoguru.com/scientist/statistics/

DOE Sequence



Steepest Ascent

- Start with a factorial design (linear model) about the current process (Plan of Record, POR)
  - In scaled coordinates, $x_1 = x_2 = \ldots = 0$ represents the center point (POR)
- To move in the direction of steepest ascent (or descent if we are looking for the min response):
  - Let the jth factor have the largest $|\beta_j|$.
  - Move a distance of Δx_j = 1 in the jth factor (or smaller or larger distance based on judgement)
  - For every other factor, move a distance of $\Delta x_i = \Delta x_j \beta_i / \beta_j$
  - Measure the response at this new point. Keep moving until the response begins to go down

Sequential DOE

- It is common to start with a two-level full factorial design with repeated center points, then extend it to a central composite design if a quadratic model is needed
- This results in two blocks: control the number of center repeats to ensure uniformity and rotatability

	Factorial center repeats	Added star center repeats
2 factors	n	n
3 factors	1.4n + 0.5	n
4 factors	2n	n
6 factors	4n – 16	n

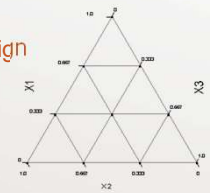
Mixtures: Factors with Constraints

- Consider the case where all factors are constrained as $0 \le x_i \le 1$,

$$x_1 + x_2 + \cdots + x_k = 1$$

- The best DOE is a simplex design with each factor taking $m + 1$ evenly spaced values

$$x_i = 0, \frac{1}{m}, \frac{2}{m}, \ldots, 1$$



http://www.itl.nist.gov/div898/handbook/pri/section5/pri542.htm

Taguchi Methods

Statistical Methods for improving quality, for example, in manufactured goods, based on three concepts:

1. Optimization involves the use of a loss function (with three types)
   - The more the better (e.g., production output): use monotonic loss function
   - The less the better (e.g., pollution emissions): use monotonic loss function
   - Hitting a target with minimum variation: Use quadratic loss function
2. Quality begins by designing a process with inherently high quality
3. Use Design of Experiments

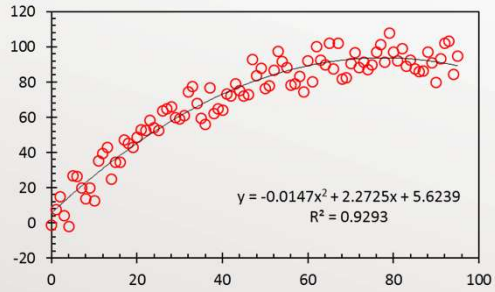
THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Cautions about DOE and RSM

- Some engineers use DOE, and especially response surface methods, as a crutch
  - Optimize a process without ever understanding the process (without asking why)
  - The design assumes a model, and so the model always fits – there is no way to test for model error!
  - A quadratic model will always show you an optimum point, but its accuracy depends on the accuracy of the model
    - Ex: Exponential data fit with a quadratic model will show an optimum that does not exist

THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Fitting an Exponential with a Quadratic



THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Lecture 72: What have we learned?

- Explain sequential DOE
- What is the simplex design and when is it used?
- Describe the Taguchi methods
- What are some of the cautions about using DOE and RSM?