

Gaining Product Understanding with DOE



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Product Understanding with DOE

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Agenda

- **Design of Experiments (DOE) Fundamentals**
- **Model Building**
- **Ways to understand**

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DOE Fundamentals

Tools

- **Factorial Designs – link to aliasing, <http://bit.ly/1cIsZQN>**
 - Full (2^k form)
 - Fractional (2^{k-p} form)
 - Taguchi - maximum assumptions
- **Advanced Designs (Response Surface Methods)**
 - 3 level (not a 3^k form)
 - 5 level (composite with factorial as a basis)
 - Optimization
- **Related Statistical Tools**
 - Statistical Process Control (SPC)
 - Gage R&R studies (measurement system assessment)
 - Probabilistic Failure Assessment (PFA)
 - New use of old tools (Monte Carlo analysis)

Typical DOE Equations (for 3 variables)

One Factor At a Time (OFAT) typical output (main effects)

$$y = z + a*A + b*B + c*C$$

Factorial typical output (main and interactions)

$$y = z + a*A + b*B + c*C + d*A*B + e*A*C + f*B*C + g*A*B*C$$

Response Surface typical output (main, interactions, quadratic)

$$y = z + a*A + b*B + c*C + d[A]^2 + e[B]^2 + f[C]^2 + g[AB] + h[AC] + i[BC] + j[ABC] + p[A]^3 + q[B]^3 + r[C]^3 + s[A^2B] + t[AB^2] + u[A^2C] + v[AC^2] + w[B^2C] + x[BC^2]$$

TYPICAL DOE TEST TABLE

Test #	Variable			Response			
	A	B	C	1	2	3	4
1	-	-	-				
2	+	-	-				
3	-	+	-				
4	+	+	-				
5	-	-	+				
6	+	-	+				
7	-	+	+				
8	+	+	+				

Model Building

- **Reliability modeling is a common practice for understanding reliability requirements**
- **Product modeling is done to understand performance**
 - **How is product modeling done?**
 - Solid models (does it fit together)
 - Simulations (scientific knowledge, how we expect it to work)
 - DOE (empirical – how it actually works)
- **We can also have models for cost (development and unit), for schedule, etc.**

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Model Building

- **The purpose of several tools is to create an equation**
 - $Y = z + a * A + b * B + c * A * B + \text{error}$
- **This is from ANOVA, regression and DOE techniques**

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Statistical Assumptions

- In model building, we need to be concerned with:
 - Constant variance
 - Normality of residual
 - Independence
- Why do we care?
- Is this a purist approach?

Residual Analysis Overview

- Key assumptions during statistical analysis need to be checked
 - Link to DOE analysis, <http://bit.ly/126UFJt>
- This allows additional learning to take place
- Residual is another word for “error” – so we are also checking the errors observed and ensuring they are “random”
 - Avoiding unintended bias

Key Diagnostics

- **Outlier evaluation of test runs**
- **Normal probability plot of residuals**
- **Data “independence”**
 - **Residual vs variable: “equal” variance check**
 - **Residual trends**
 - residuals vs predicted
 - residuals vs run
 - predicted vs actual

DOE Learning

- **Model building**
 - **Main effects**
 - **Interactions**
 - **Quadratic and other advanced terms**
- **Residual analysis**
- **Robust Design**
 - **Link to prior talk, <http://bit.ly/2fNzpnL>**
 - **Link to video, <http://bit.ly/1jleFNp>**

Statistical Tolerancing Demo

- We will look at a vibration situation
- The performance equation is known

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The screenshot shows a Microsoft Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1																
2	Output - Damping Frequency															
3	wd		0.707107	hz												
4																
5	Input															
6	c		2	capacitance												
7	m		1	mass												
8	k		2	stiffness												
9	wa		1	natural frequency												
10																
11																
12																
13																
14																
15	Subcalculation															
16	q		0.707107	system quality												
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																
31																
32																
33																
34																
35																
36																
37																

The Distribution Gallery dialog box for cell C7 is open, showing the following options:

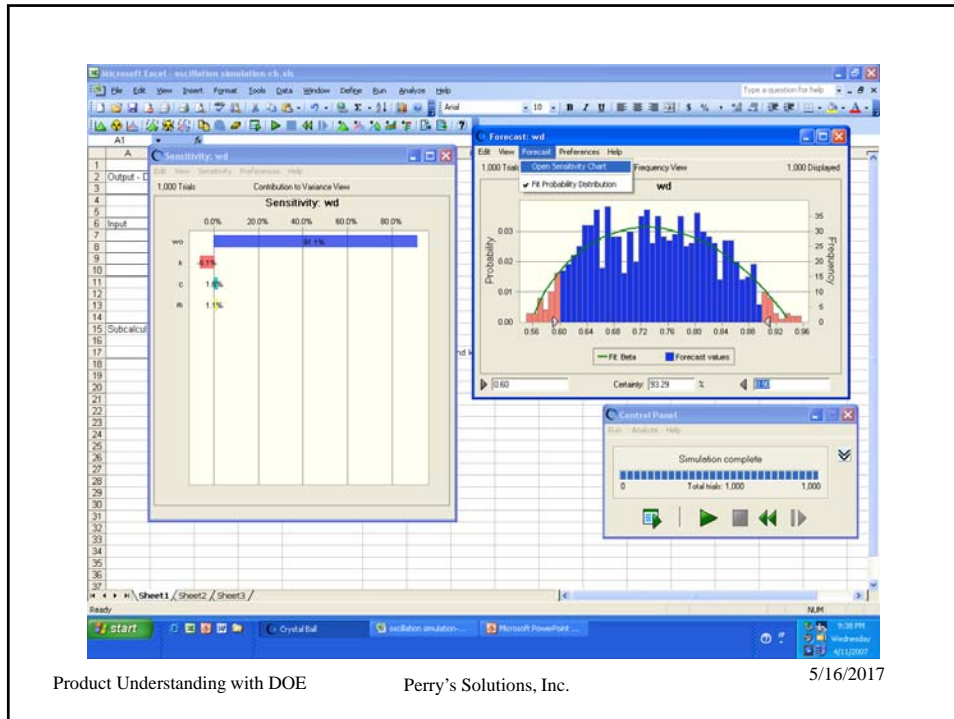
- All
- Basic
- Favorites
- Normal
- Triangular
- Uniform
- Lognormal
- Yes-No
- Discrete Uniform

The Triangular distribution is selected. The description reads: "The triangular distribution shows the number of successes when you know the minimum, maximum, and most likely values. For example, you could describe the number of cars sold per week when past sales show the minimum, maximum, and most likely number of cars sold. It is a continuous probability distribution." The parameters for the triangular distribution are minimum, likelihood, and maximum.

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Case Study

- **Goal: Resolve product field issues**
- **Response: Need to quantify and validate a measurement system**
 - Shelf life, accuracy, customer feedback
- **Approach: After resolving “obvious” issues, find a DOE sweet spot for the tunable variables.**
 - Obvious issues resolved with solid models or simulations
 - Non-obvious issues are addressed with DOE

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Conclusion

- **Confident Product Modeling is available with DOE approach**
- **Early DOE work can provide the foundation for knowledge based decisions**
- **If you want to see reference materials – visit our website**
 - www.PerrysSolutions.com
 - **If interested, email us to be on our quarterly newsletter where we share recent trends and learning points**
 - Newsletters are all archived on our publications page