Department of ESE **KRP**
Univ. of Connecticut **Spring 2013**

ECE 6161
Problem Set # 3: Robust Design

1. The thickness of a processed material is a critical dimension with specifications of [0.49, 0.51] and a designed target value of 0.5. Your internal customer has indicated that any time the thickness deviates from the design target by more than ±0.004; you are required to complete an extra $8.00 processing step.

   a) Compute the monetary constant, *k*, to be used in the quadratic loss function.
   b) Compute the average loss if your process has $\bar{y} = 0.499$ and σ=0.008.
   c) Find the total loss for one year if n = 100,000 per year.
   d) If reducing σ to 0.00$\underline{4}$ is estimated to cost $750,000, will this improvement be a good investment? (assume $\bar{y} = 0.499$)

2. A company that manufactures can-forming equipment wants to setup an experiment to help understand the factors influencing surface finish on a particular steel sub-assembly. Three factors were chosen to be varied in the experiments. The factors were:

Factor Name	Low Level	High Level
A - RPM	588	1182
B - Feed Rate	.004	.008
C - Tool Radius	1/64	1/32

   a) Generate a design matrix representing possible combinations.
   b) Suppose changing the tool radius requires an 8-hour tear-down procedure. Discuss strategies for limiting the number of times tool radius must be changed.

3. The company in the previous problem decides to test an 8-run full factorial design with the three factors at 2 levels. A brainstorming session conducted with the operator, supervisor, and engineer on the response resulted in the finished part being measured at 4 places. The design and resultant response values were as follows:

Run #	RPM	Feed Rate	Tool Radius	Measure-ment 1	Measure-ment 2	Measure-ment 3	Measure-ment 4
1	588	.004	1/64	50	50	55	50
2	588	.004	1/32	145	150	100	110
3	588	.008	1/64	160	160	155	160
4	588	.008	1/32	180	200	190	195
5	1182	.004	1/64	60	60	60	55
6	1182	.004	1/32	25	35	35	30
7	1182	.008	1/64	160	160	160	160
8	1182	.008	1/32	80	70	70	80

   a) Calculate the averages, effects, and half-effects for all factors and interactions. Plot the average values for each factor.
   b) Generate a Pareto chart of the absolute value of each half-effect. Which effects appear to be most important?
   c) Write the prediction equation.

d) Find the optimal settings for each factor assuming that the response is to be minimized and predict the response at the optimal settings.

4. In an injection molding process for the manufacture of a plastic part, a part width of 9.380 is desired. The experimenter decided to look for interactions among four factors found to be significant from a previous experiment:

- D: Mold Temperature
- A: Injection Velocity
- E: Hold Pressure
- B: Cooling Time

Run #	D	A	E	B=DAE	y_1	y_2
1	-	-	-	-	9.34150	9.34160
2	-	-	+	+	9.36914	9.36916
3	-	+	-	+	9.34666	9.34664
4	-	+	+	-	9.36801	9.36809
5	+	-	-	+	9.36790	9.36800
6	+	-	+	-	9.34933	9.34937
7	+	+	-	-	9.36680	9.36690
8	+	+	+	+	9.35444	9.35446

Analyze the experimenter's results and derive a predictive equation for width. What are the best settings to reach the 9.38 goal for width.

5. A statistical process control analyst is trying to determine which factors have a major effect in a circuit board etching process. She wants to pare down the seven factors brought out in the brainstorming session to maybe two or three. The seven factors are:

	Low	High
• A: Resist Thickness	.1mm	.5mm
• B: Develop Time	80 sec.	90 sec.
• C: Develop Concentration	3.1:1	2.7:1
• D: Exposure	200	240
• E: Develop Temperature	19^0C	23^0C
• F: Circuit Line Thickness	1mm	3mm
• G: Rinse Time	5 sec.	10 sec.

She ran the following $L_8(2^7)$ design to find the significant effects.

Run #	A	B	C	D	E	F	G	Response
1	-	-	-	-	-	-	-	74.48
2	-	-	-	+	+	+	+	70.07
3	-	+	+	-	-	+	+	75.71
4	-	+	+	+	+	-	-	68.79
5	+	-	+	-	+	-	+	84.98
6	+	-	+	+	-	+	-	81.57
7	+	+	-	-	+	+	-	84.03
8	+	+	-	+	-	-	+	80.97

a) Determine which factors affect the response variable?
b) If the goal is to maximize the response, what settings should be used? Predict what the response should be.
c) The analyst ran confirmation runs to see if she had all the effects under control. If the mean of those runs is 86, is there any problem? How about 90? 72?

6. A metal casting process for manufacturing turbine blades has four controllable factors:

- A: Metal Temperature
- B: Mold Temperature
- C: Pour Speed
- D: Raw Material

The blades must be 3mm thick; the ambient temperature causes the blades to expand and contract. The following experiment was run with ambient temperature as an outer array.

Run #	A	B	C	D	Temp L	Temp M	Temp H
1	+	+	+	+	3.06	3.14	3.06
2	+	+	-	-	3.01	3.00	3.05
3	+	-	+	-	2.81	2.81	2.80
4	+	-	-	+	2.80	2.88	3.01
5	-	+	+	-	2.62	2.61	2.62
6	-	+	-	+	2.61	2.66	2.72
7	-	-	+	+	2.42	2.43	2.52
8	-	-	-	-	2.42	2.43	2.41

a) Find a combination of settings that will produce the required thickness and is also robust to ambient temperature.
b) Plot the interactions of each factor with the ambient temperature.
c) Use the plots from b) to verify the optimal conditions found in a).