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Section 1

MANE 6313

Subsection 1

Week 11, Module A

Student Learning Outcome

- Select an appropriate experimental design with one or more factors,
- Select an appropriate model with one or more factors,
- Evaluate statistical analyses of experimental designs,
- Assess the model adequacy of any experimental design, and
- Interpret model results.

Module Learning Outcome

Describe a general 2^(k-p) fractional factorial design.

2^{8-3}

The general 2^{k-p} Fractional Factorial Design

- A 2^k fractional factorial design containing 2^{k-p} runs is called a $1/2^p$ fraction of the 2^k design
- These designs requires p independent generators (same definition from last week).
- There are $2^p - p - 1$ generalized interactions included
- There is an "art" to selecting the correct generators. Look to table 8.14 (page 353) for suggestions.

$2^3 - 3 - 1 = 4$

Resolution III Designs

- It is possible to construct resolution III designs for investigating up to $k = N - 1$ factors in N runs when N is a multiple of 4
- These experiments are said to be *saturated*
- Pay particular attention to Sequential assembly of fractions to separate effects.

Problem 8_37 (Textbook 9th Edition)

8.37 An article in *Soldering & Surface Mount Technology* ("Characterization of a Solder Paste Printing Process and Its Optimization," 1999, Vol. 11, No. 3, pp. 23–26) describes the use of a 2^{8-3} fractional factorial experiment to study the effect of eight factors on two responses; percentage volume matching (PVM) – the ratio of the actual printed solder paste volume to the designed volume; and nonconformities per unit (NPU)—the number of solder paste printing defects determined by visual inspection (20′ magnification) after printing according to an industry workmanship standard. The factor levels are shown below and the test matrix and response data are shown in Table P8.9.

Figure 1: Problem 8.37 Statement

Parameters	Levels	
	Low (−)	High (+)
A. Squeegee pressure, *MPa*	0.1	0.3
B. Printing speed, *mm/s*	24	32
C. Squeegee angle, *deg*	45	65
D. Temperature, *°C*	20	28
E. Viscosity, *kCps*	1,100-1,150	1,250-1,300
F. Cleaning interval, *stroke*	8	15
G. Separation speed, *mm/s*	0.4	0.8
H. Relative humidity, %	30	70

Full factorial A - E

F = ABC

G = ABD

H = BCDE

(a) Verify that the generators are $I = ABCF$, $I = ABDG$, and $I = BCDEH$ for this design.

(b) What are the aliases for the main effects and two-factor interactions? You can ignore all interactions of order three and higher.

(c) Analyze both PVM and NPU responses.

(d) Analyze the residual for both responses. Are there any problems with model adequacy?

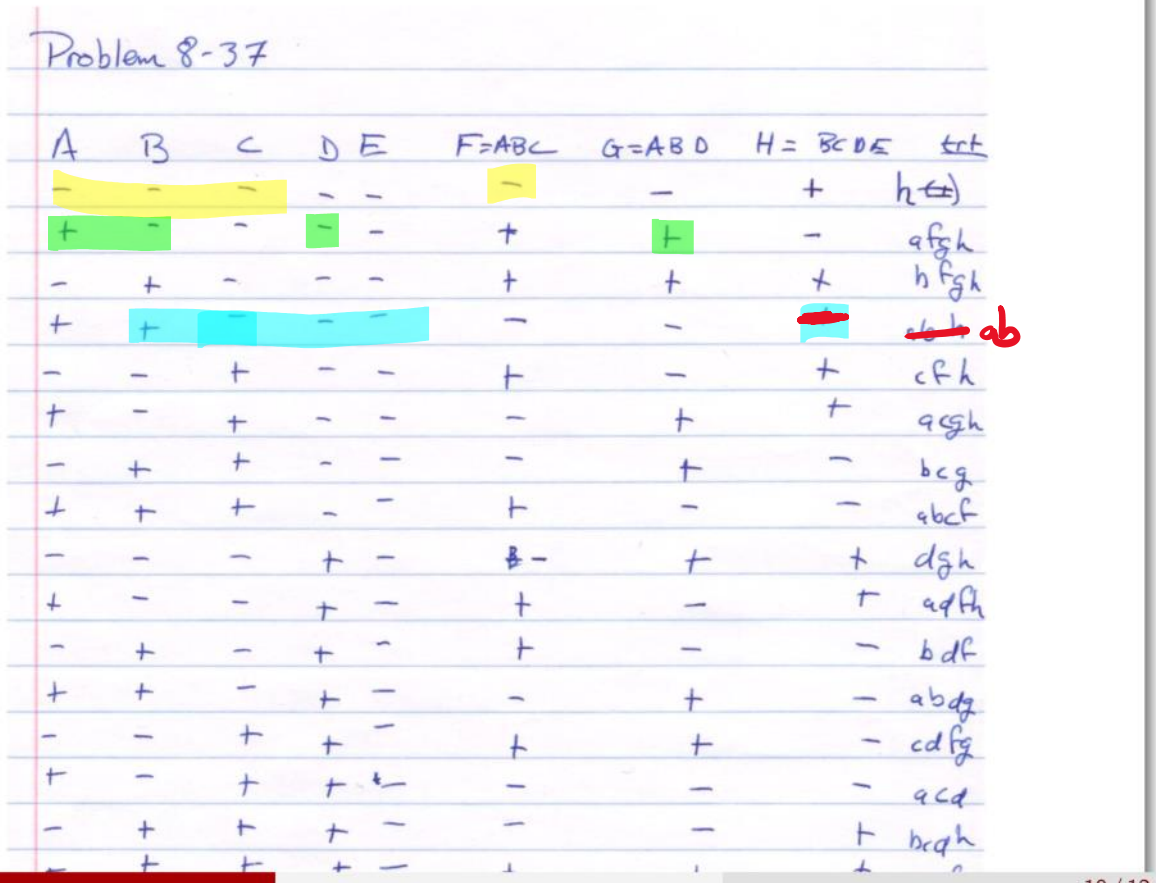
(e) The ideal value of PVM is unity and the NPU response should be as small as possible. Recommend suitable operating conditions for the process based on the experimental results.

$2^5 = 32$ runs

■ TABLE P8.9
The Solder Paste Experiment

Run Order	Parameters A	B	C	D	E	F	G	H	PVM	NPU (%)
4	−	−	−	−	−	−	−	+	1.00	5
13	+	−	−	−	−	+	+	+	1.04	13
6	−	+	−	−	−	+	+	−	1.02	16
3	+	+	−	−	−	−	−	−	0.99	12
19	−	−	+	−	−	+	−	−	1.02	15
25	+	−	+	−	−	−	+	−	1.01	9
21	−	+	+	−	−	−	+	+	1.01	12
14	+	+	+	−	−	+	−	+	1.03	17
10	−	−	−	+	−	−	+	−	1.04	21
22	+	−	−	+	−	+	−	−	1.14	20
1	−	+	−	+	−	+	−	+	1.20	25
2	+	+	−	+	−	−	+	+	1.13	21
30	−	−	+	+	−	+	+	+	1.14	25
8	+	−	+	+	−	−	−	+	1.07	13
9	−	+	+	+	−	−	−	−	1.06	20
20	+	+	+	+	−	+	+	−	1.13	26
17	−	−	−	−	+	−	−	−	1.02	10
18	+	−	−	−	+	+	+	−	1.10	13
5	−	+	−	−	+	+	+	+	1.09	17
26	+	+	−	−	+	−	−	+	0.96	13
31	−	−	+	−	+	+	−	+	1.02	14
11	+	−	+	−	+	−	+	+	1.07	11
29	−	+	+	−	+	−	+	−	0.98	10
23	+	+	+	−	+	+	−	−	0.95	14
32	−	−	−	+	+	−	+	+	1.10	28
7	+	−	−	+	+	+	−	+	1.12	24
15	−	+	−	+	+	+	−	−	1.19	22
27	+	+	−	+	+	−	+	−	1.13	15
12	−	−	+	+	+	+	+	−	1.20	21
28	+	−	+	+	+	−	−	−	1.07	19
24	−	+	+	+	+	−	−	+	1.12	21
16	+	+	+	+	+	+	+	+	1.21	27

Design, part 1



Design, part 2

Problem 8-37, continued

A	B	C	D	E	F=ABC	G=ABD	H=BCDE	trt
−	−	−	−	+	−	−	−	e
+	−	−	−	+	+	+	−	aefg
−	+	−	−	+	+	+	+	befgh
+	+	−	−	+	−	−	+	abe
−	−	+	−	+	+	−	+	cefh
+	−	+	−	+	−	+	+	acegh
−	+	+	−	+	−	+	−	bceg
+	+	+	−	+	+	−	−	abcef
−	−	−	+	+	−	+	+	degh
+	−	−	+	+	+	−	+	adefh
−	+	−	+	+	+	−	−	bdef
+	+	−	+	+	−	+	−	abdeg
−	−	+	+	+	+	+	−	cdefgh
+	−	+	+	+	−	−	−	acde
−	+	+	+	+	−	−	+	bcdefh
+	+	+	+	+	+	+	+	abcdefgh

Defining Relation

Defining Relation

Let $P = ABCF$, $Q = ABDG$, $R = BCDEH$

Then the defining relation is $2^3 - p - 1 \rightarrow 2^3 - 3 - 1 = 4$

2 at a time $\binom{3}{2} = \frac{3!}{2!(3-2)!}$

$I = P = Q = R = PQ = PR = QR = PQR$

one at a time 3 at a time

$= ABCF = ABDG = BCDEH = A^2B^2CDFG = AB^2C^2DEFH$

$= AB^2CD^2EGH = A^2B^3C^2D^2EFGH$

$= ABCF = ABDG = BCDEH = CDFG = ADEFH$

$= ACEGH = BEFGH$ ✓