R Exercises-Session 5

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1. TR 18532:2009 12.1.4.2.3 Pages 154-155

> On Silk screen printing, visual blemishes, termed "trail-marks" are being experienced. Squeegee speed, ink viscosity and dwell time were investigated. Factors and levels are shown in Table 1 below.
>
> Ten blank sheets of polyester material were taken from each run of a standard 2^3 design and a defect count was taken with the aid of a 200 square matrix. The total number of squares affected by trail-marks was counted for each run. This response was then recorded as a percentage. Resuts are shown in Table 2.

Design Factor	Level 1	Level 2
Squeegee speed	45	80
Ink viscocity	700 mPa.s	2,200 mPa.s
Dwell time	Auto	4.5

Table 1: Silk screen printing design factors and levels

Run	Squeegee speed	Ink viscosity	Dwell time	% Trail marks
1	−	−	−	0.00
2	+	−	−	1.05
3	−	+	−	5.40
4	+	+	−	0.05
5	−	−	+	0.20
6	+	−	+	0.05
7	−	+	+	5.85
8	+	+	+	0.00

Table 2: Results from the runs on the silk screen printing experiment

(a) Create a 2^3 factorial design.

```
library(FrF2)
des <- FrF2(nruns=8, randomize=FALSE,
factor.names=c("SqueegeeSpeed","InkViscosity","DwellTime"))
```


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(b) Add results in C8 and make a cube plot.

```
C8 <- c(0.00, 1.05, 5.40, 0.05, 0.20, 0.05, 5.85, 0.00)
des.resp <- add.response(des, response = C8)
cubePlot(lm(des.resp, degree=3),
"SqueegeeSpeed","InkViscosity","DwellTime", modeled=F)
```

(c) Analyse the experiment.

```
coef(lm(des.resp, degree=3))
DanielPlot(des.resp)
MEPlot(des.resp)
IAPlot(des.resp)
```

2. TR 18532:2009 12.1.4.2.2 Pages 150-154

> This example shows an application of experimental design 2 of Table 32. It has two roles; one, as a design development tool to determine the suitability of a sintered part for a particular application and two, as a development tool in the sense of searching for preferred operating conditions. Four design factors were investigated each at two levels as indicated in Table 3.
>
> The experimental layout uses columns 1, 2, 4, and 7 of a standard $L8$ array. Strength of fit, in kN, at minimum interference conditions was recorded for each part subjected to each experimental combination.
>
> Three parts were used for each run in order to separate means from variation in order to permit a search for design factors that would enhance mean strength (signal factors) and those that would reduce variation (control factors). Variation is expressed in terms of standard deviation. The results are given in Table 4.

Design Factor	Level 1	Level 2
A: Surface finish	Fine turned	Microlled
B: Lubrication	Yes–number 2 oil	No
C: Speed	Low	High
D: Density	6.5	6.8

Table 3: Sintered part design factors and their levels

(a) Create a 2^{4-1} design.

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Run	A	B	C	D	Result1	Result2	Result3	Mean	StdDev
1	-1	-1	-1	-1	12.7	7.27	9.74	9.9	2.72
2	1	-1	-1	1	10.36	10.45	9.05	9.95	0.78
3	-1	1	-1	1	12.61	15.19	14.11	13.97	1.3
4	1	1	-1	-1	16.8	14.76	13.92	15.16	1.48
5	-1	-1	1	1	9.41	8.52	7.29	8.41	1.06
6	1	-1	1	-1	7.45	8.9	10.02	8.79	1.29
7	-1	1	1	-1	13.99	7.65	8.1	9.91	3.54
8	1	1	1	1	11.52	13.92	10.33	10.33	0.74

Table 4: Results from the runs on sintered part experiment

```
SinteredPart <- FrF2(8, 4, randomize=F)
Mn <- read.csv("DOE_ExampleOne.csv")$Mean
SD <- read.csv("DOE_ExampleOne.csv")$StdDev

SinteredPart.Mn <- add.response(SinteredPart, response=Mn)
SinteredPart.SD <- add.response(SinteredPart, response=SD)
```

(b) Make cube plots of the data.

```
cubePlot(lm(SinteredPart.Mn, degree=3),
"A","B","C",modeled=F)
cubePlot(lm(SinteredPart.SD, degree=3),
"A","B","C",modeled=F)
```

(c) Analyse the experiment.

```
coef(lm(SinteredPart.Mn, degree=2))
DanielPlot(SinteredPart.Mn)
MEPlot(SinteredPart.Mn)
IAPlot(SinteredPart.Mn)
coef(lm(SinteredPart.SD, degree=2))
DanielPlot(SinteredPart.SD)
MEPlot(SinteredPart.SD)
IAPlot(SinteredPart.SD)
```

3. The Bush Experiment

In a VU student project conducted by Peter Kostaridis and Nick Condilis, an experiment was carried out to improve the rubber composition of the bush, an important part of the suspension system, used in a locally manufactured car. The levels of six components were varied and the resulting compound was tested to determine the Loss Angle and Dynamic Stiffness. The factors have been coded as 301 (A), 302 (B), 303 (C), 304 (D), 308 (E), and 309 (F) for confidentiality reasons and the levels given as $-$ and $+$. The design and results are given in Table 5.

Run	A	B	C	D	E	F	Loss Angle	Dynamic Stiffness
1	$-$	$-$	$-$	$-$	$-$	$-$	5.45	520
2	$+$	$-$	$-$	$+$	$+$	$+$	4.55	501
3	$-$	$+$	$-$	$+$	$+$	$-$	7.23	864
4	$+$	$+$	$-$	$-$	$-$	$+$	6.11	999
5	$-$	$-$	$+$	$-$	$+$	$+$	4.93	573
6	$+$	$-$	$+$	$+$	$-$	$-$	6.37	523
7	$-$	$+$	$+$	$+$	$-$	$+$	5.59	946
8	$+$	$+$	$+$	$-$	$+$	$-$	7.72	686

Table 5: Design and results for the Bush Experiment

(a) Read the design and results into R and set up the Experimental Design.

```
Bush <- read.csv("Bush1.csv")
lm(D ~ (A+B+C)^3, data=Bush)
lm(E ~ (A+B+C)^3, data=Bush)
lm(FF ~ (A+B+C)^3, data=Bush)

BushDesign <- FrF2(8, 6, randomize=FALSE,
generators=c("-AB", "ABC", "-AC"))

BushDesign.LA <- add.response(BushDesign, Bush$LossAngle)
BushDesign.DS <- add.response(BushDesign, Bush$DynamicStiffness)
```

(b) Analyse the experiment.

```
coef(lm(BushDesign.LA, degree=2))
DanielPlot(BushDesign.LA)
MEPlot(BushDesign.LA)

coef(lm(BushDesign.DS, degree=2))
DanielPlot(BushDesign.DS)
MEPlot(BushDesign.DS)
```


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4. Explosives Development

In the development of a new explosive, a set of experiments were run involving five factors with A, Age of Gum; B, Age of Thiourea; C, pH controlled; D, Aluminium level; and E, Crosslinker Level. The response was the Gel Strength after 10 minutes. The design and results are given in Table 6.

A	B	C	D	E	Gel Strength (10 Mins)
−	−	−	−	+	469
+	−	−	−	−	330
−	+	−	−	−	266
+	+	−	−	+	351
−	−	+	−	−	316
+	−	+	−	+	522
−	+	+	−	+	357
+	+	+	−	−	430
−	−	−	+	−	293
+	−	−	+	+	708
−	+	−	+	+	267
+	+	−	+	−	341
−	−	+	+	+	502
+	−	+	+	−	453
−	+	+	+	−	197
+	+	+	+	+	568

Table 6: Design and results for the Explosives Development Experiment

(a) Read the design and results into R and set up the Experimental Design.

```
GelStrength <- c(469, 330, 266, 351,
316, 522, 357, 430,
293, 708, 267, 341,
502, 453, 197, 568)
Explosives <- FrF2(16, 5, randomize = F)
Explosives.resp <- add.response(Explosives, response=GelStrength)
```

(b) Analyse the experiment.

```
coef(lm(Explosives.resp, degree=2))
DanielPlot(Explosives.resp)
MEPlot(Explosives.resp)
IAPlot(Explosives.resp)
```

(c) Make a cube plot.

```
cubePlot(lm(Explosives.resp, degree=2),"A","B","E",
modeled=F)
```

5. Injection Molding Experiment

In an injection molding experiment eight variables were studied in 16 runs. The response was percentage shrinkage. The variables are given in Table 6 while the design and results are given in Table 7.

A	Mold Temperature
B	Moisture Content
C	Holding Pressure
D	Cavity Thickness
E	Booster Pressure
F	Cycle Time
G	Gate Size
H	Screw Speed

Table 7: Variables for Injection Molding Experiment

Run	A	B	C	D	E	F	G	H	Shrinkage
1	−	−	−	−	−	−	−	−	20.3
2	+	−	−	−	−	+	+	+	16.8
3	−	+	−	−	+	−	+	+	15.0
4	+	+	−	−	+	+	−	+	15.9
5	−	−	+	−	+	+	+	−	17.5
6	+	−	+	−	+	−	−	+	24.0
7	−	+	+	−	−	+	−	+	27.4
8	+	+	+	−	−	−	+	−	22.3
9	−	−	−	+	+	+	−	−	14.0
10	+	−	−	+	+	−	+	+	16.7
11	−	+	−	+	−	+	+	−	21.9
12	+	+	−	+	−	−	−	+	15.4
13	−	−	+	+	−	−	+	+	27.6
14	+	−	+	+	−	+	−	−	21.5
15	−	+	+	+	+	−	−	−	17.1
16	+	+	+	+	+	+	+	+	22.6

Table 8: Design and results for the Injection Molding Experiment

(a) Read the design and results into R and set up the Experimental Design.

```
InjectionMolding <- read.csv("InjectionMolding.csv")
lm(E ~ (A*B*C*D), data=InjectionMolding)
lm(F ~ (A*B*C*D), data=InjectionMolding)
lm(G ~ (A*B*C*D), data=InjectionMolding)
lm(H ~ (A*B*C*D), data=InjectionMolding)
```


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```
InjectionMoldingDesign <- FrF2(16, 8, randomize=FALSE,
generators=c("BCD", "ACD", "ABC", "ABD"))

InjectionMolding.resp <- add.response(BushDesign,
InjectionMolding$Shrinkage)
```

(b) Analyse the experiment.

```
coef(lm(InjectionMolding.resp, degree=2))
DanielPlot(InjectionMolding.resp)
MEPlot(InjectionMolding.resp)
IAPlot(InjectionMolding.resp)
```

6. Response Surface Example TR18532:2009 Pages 156-158.

Technical and operational considerations indicate that three factors, gas ratio, power and pulse may influence oxide uniformity. Non-linearity and interactions are expected so each factor was investigated at three levels using an 18 run central composite (face-centred cube) design. The three levels of each factor were coded −1, 0, and 1 for convenience. Results are shown in Table 8.

Gas Ratio	Pulse	Power	Oxide Uniformity
0	0	0	29.4
0	0	0	32.1
0	0	0	31.5
0	0	0	30.9
−1	−1	−1	16.9
−1	1	−1	17.2
−1	1	1	22.7
−1	−1	1	52.4
1	−1	−1	10.7
1	1	−1	22.6
1	1	1	23.8
1	−1	1	43.5
0	−1	0	32.7
0	0	−1	16.4
0	1	0	24.1
0	0	1	37.5
−1	0	0	27.6
1	0	0	31.8

Table 9: Results for experiment runs on etching process

(a) Read the design and results into R and set up the Experimental Design.

```
oxide <- read.csv("rsmexample.csv")
```

(b) Analyse the experiment.

```
oxide.rsm <- rsm(OxideUniformity ~
SO(GasRatio,Pulse, Power), data=oxide)
summary(oxide.rsm)
contour(oxide.rsm, ~ GasRatio+Pulse+ Power)
```