

Math 3080 § 1.
Treibergs

Metal Rod Example:
2³ Factorial Experiment

Name: Example
Feb. 8, 2014

We describe a 2³ experimental design with one replicate per cell. It comes from an experiment by Heinrich, "Experimental Design: Applications to System Testing," *Quality Engineering* 1, (1989) 199-216, who tested the tensile strength of metal rods depending on manufacturing conditions. Quoted from Levine, Ramsey and Smidt, *Applied Statistics for Engineers and Scientists*, Prentice Hall, 2001.

Data Set Used in this Analysis :

```
# Math 3080 - 1           Metal Rod Data           Feb. 9, 2014
# Treibergs
#
# An experiment by Heinrich, "Experimental Design: Applications to System
# Testing," Quality Engineering 1, (1989) 199-216 tested the tensile
# strength of metal rods depending on manufacturing condidiont. Quoted from
# Levine, Ramsey and Smidt, Applied Statistics for Engineers and
# Scientists, Prentice Hall, 2001.
#
# Factors      (Levels)
# Temperature of the molten metal at start (300 F, 400 F)
# Pressure on the molten metal to force it through the die (40 psi, 70 psi)
# Amount of catalyst (20 rpm, 30 rpm)
#
"Temp" "Pressure" "Catalyst" "Tensile"
300 40 20 30
400 40 20 20
300 70 20 20
400 70 20 30
300 40 30 10
400 40 30 60
300 70 30 10
400 70 30 10
```

R Session:

```
R version 2.13.1 (2011-07-08)
Copyright (C) 2011 The R Foundation for Statistical Computing
ISBN 3-900051-07-0
Platform: i386-apple-darwin9.8.0/i386 (32-bit)
```

```
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.
```

```
Natural language support but running in an English locale
```

```
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
```

'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or

'help.start()' for an HTML browser interface to help.

Type 'q()' to quit R.

[R.app GUI 1.41 (5874) i386-apple-darwin9.8.0]

[History restored from /Users/andrejstreibergs/.Rapp.history]

```
> tt=read.table("M3082DataMetalRod.txt",header=T)
> attach(tt)
> tt
  Temp Pressure Catalyst Tensile
1  300        40        20      30
2  400        40        20      20
3  300        70        20      20
4  400        70        20      30
5  300        40        30      10
6  400        40        30      60
7  300        70        30      10
8  400        70        30      10
> temp=ordered(Temp); pressure=ordered(Pressure); cat=ordered(Catalyst)

> ##### ANALYSIS OF VARIANCE #####
> a1=aov(Tensile~temp+pressure+cat)
> summary(a1)
              Df Sum Sq Mean Sq F value Pr(>F)
temp           1  312.5   312.5  0.9259 0.3904
pressure       1  312.5   312.5  0.9259 0.3904
cat            1   12.5    12.5  0.0370 0.8568
Residuals     4 1350.0   337.5

> ##### INTERACTION AND DESIGN PLOTS #####
> layout(matrix(c(1,4,2,3),ncol=2))
> interaction.plot(temp,pressure,Tensile,main="Interaction Plots")
> interaction.plot(temp,cat,Tensile)
> interaction.plot(pressure,cat,Tensile)
> plot.design(Tensile~temp+pressure+cat)
```

```
> ##### TABLES OF MEANS AND EFFECTS #####
```

```
> model.tables(a1,"means")
```

```
Tables of means
```

```
Grand mean
```

```
23.75
```

```
temp
```

```
300 400
```

```
17.5 30.0
```

```
pressure
```

```
40 70
```

```
30.0 17.5
```

```
cat
```

```
20 30
```

```
25.0 22.5
```

```
> model.tables(a1)
```

```
Tables of effects
```

```
temp
```

```
300 400
```

```
-6.25 6.25
```

```
pressure
```

```
40 70
```

```
6.25 -6.25
```

```
cat
```

```
20 30
```

```
1.25 -1.25
```

```
> ##### EFFECTS AS CONTRASTS #####
```

```
> e1=sum(Tensile*c(1,1,1,1,1,1,1,1))/8; e1
```

```
[1] 23.75
```

```
> eA=sum(Tensile*c(-1,1,-1,1,-1,1,-1,1))/8; eA
```

```
[1] 6.25
```

```
> eB=sum(Tensile*c(-1,-1,1,1,-1,-1,1,1))/8; eB
```

```
[1] -6.25
```

```
> eC=sum(Tensile*c(-1,-1,-1,-1,1,1,1,1))/8; eC
```

```
[1] -1.25
```

```
> eAB=sum(Tensile*c(1,-1,-1,1,1,-1,-1,1))/8; eAB
```

```
[1] -3.75
```

```
> eAC=sum(Tensile*c(1,-1,1,-1,-1,1,-1,1))/8; eAC
```

```
[1] 6.25
```

```
> eBC=sum(Tensile*c(1,1,-1,-1,-1,1,1,1))/8; eBC
```

```
[1] -6.25
```

```
> eABC=sum(Tensile*c(-1,1,1,-1,1,-1,-1,1))/8; eABC
```

```
[1] -8.75
```

```

> ### QQ-PLOT OF CONTRASTS TO FIND SIGNIFICANT EFFECTS #####
> eff=c(e1,eA,eB,eAB,eC,eAC,eBC,eABC); eff
[1] 23.75  6.25 -6.25 -3.75 -1.25  6.25 -6.25 -8.75
> qqnorm(eff); qqline(eff)
> plot(a1)

> ##### EFFECTS 2 (A) AND 6 (AC) SEEM TO DIFFER FROM LINE #####
> ##### SO MAY BE SIGNIFICANT. #####

```

Interaction Plots



