**228.371 Assignment 3**

**Assessed lab: June 18, 2014**

**Question 3 – Fractional Factorial Design**

A welding technologist conducted an unreplicated two-level fractional factorial experiment to study how five hypothesised factors (Table 3.1) affect welding current in gas metal arc welding, a common technique used in welding Aluminium plates. The objective of the experiment was to understand how the process works and characterise the system as a response function (regression equation) for conducting further experiments leading to process optimisation (minimising welding current would be one optimisation objective).

**Table 3.1:** Factors and Levels

|  |  |  |  |
| --- | --- | --- | --- |
| Factor Label | Factor Name | Low (-1) | High (+1) |
| A | Wire feed rate (m/min) | 6.0 | 8.0 |
| B | Arc Voltage (V) | 24 | 30 |
| C | Nozzle-to-plate distance (mm) | 15 | 20 |
| D | Welding torch angle (deg) | 80 | 100 |
| E | Welding Speed (cm/min) | 30 | 40 |

The average welding current Y (in Amps) was recorded in each run keeping the length of the weld and the plate thickness constant in each experimental run. The runs were done in a completely randomised fashion. The Minitab worksheet containing the data for this question is question 3 welding.MTW.

**Answer the following:**

3.1 Based on the alias structure provided by Minitab (you need to attempt to analyse the factorial design to get the alias structure on the session window), comment on the degree of aliasing present in the design and the confidence the technologist will have on parameter estimates provided to her by Minitab.

Your answer should cover the following key words: design resolution, main effects, two-way interactions, higher order interactions, and unreplicated.

The alias structure given by Minitab should also be shown.

[4 Marks]

<begin answer here>

Alias Information for Terms in the Model.

Totally confounded terms were removed from the analysis.

I + A\*B\*C\*D\*E

A + B\*C\*D\*E

B + A\*C\*D\*E

C + A\*B\*D\*E

D + A\*B\*C\*E

E + A\*B\*C\*D

A\*B + C\*D\*E

A\*C + B\*D\*E

A\*D + B\*C\*E

A\*E + B\*C\*D

B\*C + A\*D\*E

B\*D + A\*C\*E

B\*E + A\*C\*D

C\*D + A\*B\*E

C\*E + A\*B\*D

D\*E + A\*B\*C

**Results for: question 3 Welding.MTW**

**Factorial Fit: Y versus A, B, C, D, E**

Estimated Effects and Coefficients for Y (coded units)

Term Effect Coef

Constant 259.72

A -34.31 -17.16

B -1.51 -0.76

C -14.39 -7.19

D 11.61 5.81

E -2.06 -1.03

A\*B 1.44 0.72

A\*C -17.09 -8.54

A\*D -1.19 -0.59

A\*E -4.41 -2.21

B\*C -2.54 -1.27

B\*D -2.94 -1.47

B\*E -1.21 -0.61

C\*D 1.44 0.72

C\*E 0.16 0.08

D\*E -1.44 -0.72

S = \* PRESS = \*

Analysis of Variance for Y (coded units)

Source DF Seq SS Adj SS Adj MS F P

Main Effects 5 6102.96 6102.96 1220.59 \* \*

A 1 4709.39 4709.39 4709.39 \* \*

B 1 9.15 9.15 9.15 \* \*

C 1 828.00 828.00 828.00 \* \*

D 1 539.40 539.40 539.40 \* \*

E 1 17.02 17.02 17.02 \* \*

2-Way Interactions 10 1342.51 1342.51 134.25 \* \*

A\*B 1 8.27 8.27 8.27 \* \*

A\*C 1 1167.93 1167.93 1167.93 \* \*

A\*D 1 5.64 5.64 5.64 \* \*

A\*E 1 77.88 77.88 77.88 \* \*

B\*C 1 25.76 25.76 25.76 \* \*

B\*D 1 34.52 34.52 34.52 \* \*

B\*E 1 5.88 5.88 5.88 \* \*

C\*D 1 8.27 8.27 8.27 \* \*

C\*E 1 0.11 0.11 0.11 \* \*

D\*E 1 8.27 8.27 8.27 \* \*

Residual Error 0 \* \* \*

Total 15 7445.46

**Effects Plot for Y**

Alias Structure

I + A\*B\*C\*D\*E

A + B\*C\*D\*E

B + A\*C\*D\*E

C + A\*B\*D\*E

D + A\*B\*C\*E

E + A\*B\*C\*D

A\*B + C\*D\*E

A\*C + B\*D\*E

A\*D + B\*C\*E

A\*E + B\*C\*D

B\*C + A\*D\*E

B\*D + A\*C\*E

B\*E + A\*C\*D

C\*D + A\*B\*E

C\*E + A\*B\*D

D\*E + A\*B\*C

\* NOTE \* Could not graph the specified residual type because MSE = 0 or the

degrees of freedom for error = 0.

<end answer here>

3.2 Analyse the data and write down the regression equation for Y in coded units, using 5% significance level.

Show all relevant Minitab printouts that you may consider necessary in answering the question (model adequacy should not be covered at this stage).

[7 Marks]

<begin answer here>



As showed on the graph, the significant points are A, AC, C and D.

Therefore we plot only those 4 points.



**Factorial Fit: Y versus A, C, D**

Estimated Effects and Coefficients for Y (coded units)

Term Effect Coef SE Coef T P

Constant 259.72 1.068 243.19 0.000

A -34.31 -17.16 1.068 -16.06 0.000

C -14.39 -7.19 1.068 -6.74 0.000

D 11.61 5.81 1.068 5.44 0.000

A\*C -17.09 -8.54 1.068 -8.00 0.000

S = 4.27192 PRESS = 424.710

R-Sq = 97.30% R-Sq(pred) = 94.30% R-Sq(adj) = 96.32%

The regression is Y=-17.16\*A-7.19\*C+5.81\*D-8.54\*AC

<end answer here>

3.3 Show the main effects plots and two-way interaction plots (choose all five factors) and state what the factorial plots entail, keeping in mind that the technologist is looking at minimising the welding current.

[3 Marks]

<begin answer here>



As showed on the graph, point A, C and D are significant.



It shows that BC, BD and BE have significant two-way interactions.

<end answer here>

3.4 Discuss the adequacy of your model for making future predictions. Your answer should cover comments on the relevant Factorial Fit and ANOVA results for your model as well as any graphical plot/s that you may consider necessary.

[4 Marks]

<begin answer here>

Estimated Effects and Coefficients for Y (coded units)

Term Effect Coef SE Coef T P

Constant 259.72 1.068 243.19 0.000

A -34.31 -17.16 1.068 -16.06 0.000

C -14.39 -7.19 1.068 -6.74 0.000

D 11.61 5.81 1.068 5.44 0.000

A\*C -17.09 -8.54 1.068 -8.00 0.000

S = 4.27192 PRESS = 424.710

R-Sq = 97.30% R-Sq(pred) = 94.30% R-Sq(adj) = 96.32%

Analysis of Variance for Y (coded units)

Source DF Seq SS Adj SS Adj MS F P

Main Effects 3 6076.79 6076.79 2025.60 111.00 0.000

A 1 4709.39 4709.39 4709.39 258.06 0.000

C 1 828.00 828.00 828.00 45.37 0.000

D 1 539.40 539.40 539.40 29.56 0.000

2-Way Interactions 1 1167.93 1167.93 1167.93 64.00 0.000

A\*C 1 1167.93 1167.93 1167.93 64.00 0.000

Residual Error 11 200.74 200.74 18.25

Lack of Fit 3 19.79 19.79 6.60 0.29 0.830

Pure Error 8 180.95 180.95 22.62

Total 15 7445.46

Unusual Observations for Y

Obs StdOrder Y Fit SE Fit Residual St Resid

13 16 225.500 232.631 2.388 -7.131 -2.01R

R denotes an observation with a large standardized residual.



The R squared values are high therefore regression fits well. The p value of the lack of fit is 0.83 which is significantly high. The normal probability plot and the histogram are good wich means that it is a normal distribution. The residuals are also evenly distributed therefore the regression line fit great.

<end answer here>

3.5 Using your regression model state the expected value of the minimum welding current along with the relevant factor settings.

[3 Marks]

<begin answer here>



A=8

C=20

D=80

Therefore Y= -17.16\*8-7.19\*20+5.81\*80-8.54\*8\*20=-1182.68

As Y cant be negative, therefore minimum Y is 0.

<end answer here>

3.6 What future designed experiments should the technologist consider in further optimising the process? Assume that a second response variable of interest “strength of the weld” also becomes important in the subsequent experiment. You need to justify each experiment chosen. State assumptions (if any).

[4 Marks]

<begin answer here>

<end answer here>

**[Total: 25 Marks]**