Analysis of Steel Spring Data

Steel springs are made in large batches. The percentage of good springs in a batch depends on the temperature at which the spring are made and the amount of carbon in the steel. The values of temperature at 1500 and 1600 and the values of carbon are 0.5, 0.6, and 0.7.

A plot of the means, shown in Figure 1, indicates that temperature has potentially big effect on the percentage of good springs in a batch. (This is because there is a separation between the two lines.) The amount of carbon in the steel appears to have less of an effect. (Because the slopes of the two lines are not very steep.)

The overall ANOVA F test indicates that at least one of the factors (Temperature or Carbon) significantly affects the percentages of good spring in a batch ($F = 15.52$, $p<.0001$). The interaction is not significant ($F=0.97$, $p=.4074$), but both of the main effects are significant. The tests of main effects are consistent with the information in the means plot. Temperature is highly significant ($F=63.38$, $p<.0001$). Carbon is also significant ($F=6.14$, $p=.0146$), but this is less significant than Temperature.

Since the interaction is not significant, we can interpret the estimated marginal means. For Temperature, the two levels (1500 and 1600) have significantly different mean percentage of good springs ($p<.0001$), and the percentage for temperature 1600 is higher than the mean percentage for temperature 1500 (77.44 vs. 68.78). For Carbon, three levels (0.5, 0.6 and 0.7) have means 75.5, 73.0, and 70.83 respectively. Statistically, these means are not all the same ($F=6.14$, $p=0.0146$). The mean for 0.5 level of Carbon is significantly different than the mean percentage for Carbon level 0.7 ($p = 0.0044$), but is not different from the mean for Carbon level 0.6 ($p = 0.0853$). The difference between Carbon levels 0.6 and 0.7 is not significant ($p = 0.1301$).

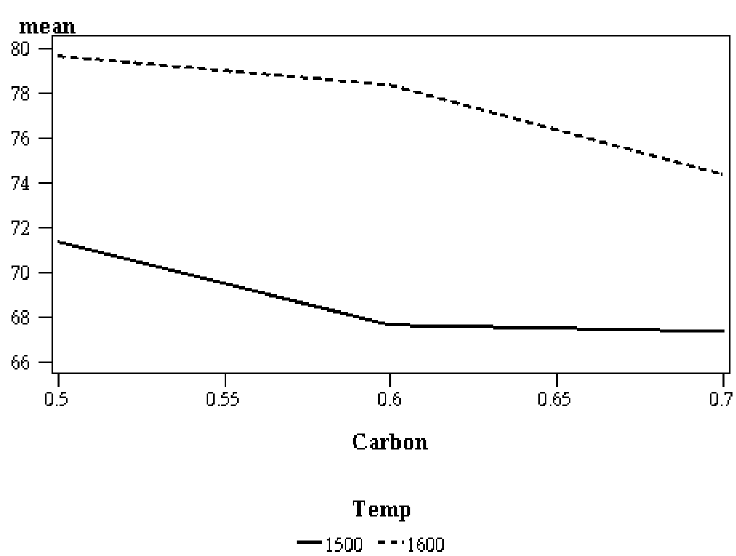

Figure 1: Interaction plot for steel springs data

SAS Code and Edited Output for Steel Springs data

```
options ls=72;
data steelsprings;
 input Temp Carbon Pct;
 datalines;
1500       0.5       75
1500       0.5       69
1500       0.5       70
1500       0.6       68
1500       0.6       68
1500       0.6       67
1500       0.7       69
1500       0.7       69
1500       0.7       64
1600       0.5       81
1600       0.5       76
1600       0.5       82
1600       0.6       79
1600       0.6       78
1600       0.6       78
1600       0.7       73
1600       0.7       76
1600       0.7       74
;


ods graphics on;

proc sort data=steelsprings;
by Temp Carbon;
 run;

proc means data=steelsprings noprint;
 by Temp Carbon;
 var Pct;
 output out=means mean=mean;
 run;

axis1 minor=none;
symbol1 i=join value=none line=1 color=black w=2;
symbol2 i=join value=none line=2 color=black w=2;

proc gplot data=means;
 plot mean*Carbon=Temp / haxis=axis1 vaxis=axis1;
 run;

proc glm data=steelsprings;
class Temp Carbon;
model Pct = Temp Carbon Temp*Carbon / ss3;
lsmeans Temp Carbon Temp*Carbon / stderr pdiff;
run;

quit;
```

The GLM Procedure

Dependent Variable: Pct

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	413.7777778	82.7555556	15.52	<.0001
Error	12	64.0000000	5.3333333		
Corrected Total	17	477.7777778			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Temp	1	338.0000000	338.0000000	63.38	<.0001
Carbon	2	65.4444444	32.7222222	6.14	0.0146
Temp*Carbon	2	10.3333333	5.1666667	0.97	0.4074

The GLM Procedure
Least Squares Means

Temp	Pct LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
1500	68.7777778	0.7698004	<.0001	<.0001
1600	77.4444444	0.7698004	<.0001	

Carbon	Pct LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
0.5	75.5000000	0.9428090	<.0001	1
0.6	73.0000000	0.9428090	<.0001	2
0.7	70.8333333	0.9428090	<.0001	3

Least Squares Means for effect Carbon
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Pct

i/j	1	2	3
1		0.0853	0.0044
2	0.0853		0.1301
3	0.0044	0.1301	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Temp	Carbon	Pct LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1500	0.5	71.3333333	1.3333333	<.0001	1
1500	0.6	67.6666667	1.3333333	<.0001	2
1500	0.7	67.3333333	1.3333333	<.0001	3
1600	0.5	79.6666667	1.3333333	<.0001	4
1600	0.6	78.3333333	1.3333333	<.0001	5
1600	0.7	74.3333333	1.3333333	<.0001	6

The GLM Procedure
Least Squares Means

Least Squares Means for effect Temp*Carbon
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Pct

i/j	1	2	3	4	5	6
1		0.0756	0.0554	0.0008	0.0030	0.1376
2	0.0756		0.8626	<.0001	0.0001	0.0041
3	0.0554	0.8626		<.0001	<.0001	0.0030
4	0.0008	<.0001	<.0001		0.4930	0.0152
5	0.0030	0.0001	<.0001	0.4930		0.0554
6	0.1376	0.0041	0.0030	0.0152	0.0554	