# 2006 MEC 623 SIX SIGMA – TEST II

Time: 60 minutes, Max marks:20

Use of approved Six Sigma Tables is permitted

1) The viscosity of a rubber is tested differently at the supplier's lab and customer's lab. Ten samples were split and sent to both the labs, with the following results:

| **Sample** | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| **Manufacturer** | 91.7 | 93.0 | 96.1 | 94.9 | 93.8 | 94.9 | 92.6 | 92.7 | 92.2 | 93.4 |
| **Customer** | 93.3 | 94.3 | 95.0 | 93.6 | 94.8 | 95.6 | 94.1 | 93.8 | 93.8 | 94.7 |

Are the two tests equivalent?

(3 marks)

2) Why historical data can never be as good as experimental data?

(3 marks)

3) A test programme is to be conducted to evaluate the performance of artillery projectiles against a variety of targets. The targets can be made of Steel, FRP, or Titanium. They can be either vertical or at an angle of $80^o$ to horizontal. The projectiles can be fired at $45^o$ or $50^o$. Design a full factorial experiment with two replications randomised in two blocks. Provide a table so that a person unfamiliar with DoE will be able to carry out the experiments.

(3 marks)

4) The results of a $2^3$ factorial design and the calculated effects are given in table below. Factors A and AB are found to be significant. Develop a hierarchical model and calculate the residuals.

| | **R1** | **R2** | **Ave** | **1** | **2** | **3** | **Effects** | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.2 | 2.4 | 1.8 | 20.3 | 40.45 | 81.55 | 10.194 | 1 |
| a | 19.6 | 17.4 | 18.5 | 20.15 | 41.1 | 40.65 | 10.163 | **a** |
| b | 8.4 | 7.9 | 8.15 | 21 | 20.55 | -1.05 | -0.263 | b |
| ab | 11.4 | 12.6 | 12 | 20.1 | 20.1 | -24.75 | -6.188 | **ab** |
| c | 2.8 | 2.2 | 2.5 | 16.7 | -0.15 | 0.65 | 0.1625 | c |
| ac | 17.4 | 19.6 | 18.5 | 3.85 | -0.9 | -0.45 | -0.112 | ac |
| bc | 7.6 | 8.4 | 8 | 16 | -12.85 | -0.75 | -0.187 | bc |
| abc | 12.5 | 11.7 | 12.1 | 4.1 | -11.9 | 0.95 | 0.2375 | abc |

(6 marks)

5) An experiment was conducted to study the effect of engine speed and load on fuel efficiency with results as follows. Is the curvature significant?

| **Speed (rpm)** | **Load (Nm)** | **R1** | **R2** |
|---|---|---|---|
| 1000 | 50 | 51 | 48 |
| 2000 | 50 | 12 | 9 |
| 1000 | 150 | 73 | 68 |
| 2000 | 150 | 33 | 29 |
| 1500 | 100 | 44 | 46 |
| 1500 | 100 | 42 | 45 |

(5 marks)

6) The factors affecting hardness of a metal part during heat treatment was suspected to be the Carbon content, Diameter, and Soaking time in the furnace. Since randomising the soaking time was difficult, an experiment was run as follows:

| A | B | Random | C | D | | | |
|---|---|---|---|---|---|---|---|
| Carbon | Dia | Sample | Time | Rep | Hardness | Effects | |
| -1 | -1 | 1 | -1 | 1 | 24 | 29.813 | 1 |
| 1 | -1 | 3 | -1 | 1 | 33 | 8.625 | A |
| -1 | 1 | 2 | -1 | 1 | 26 | -0.625 | B |
| 1 | 1 | 4 | -1 | 1 | 34 | -0.125 | AB |
| -1 | -1 | 3 | 1 | 1 | 27 | 1.375 | C |
| 1 | -1 | 4 | 1 | 1 | 34 | -0.625 | AC |
| -1 | 1 | 1 | 1 | 1 | 26 | 0.125 | BC |
| 1 | 1 | 2 | 1 | 1 | 36 | 0.625 | ABC |
| -1 | -1 | 2 | -1 | 2 | 25 | -0.375 | D |
| 1 | -1 | 4 | -1 | 2 | 36 | 0.125 | AD |
| -1 | 1 | 1 | -1 | 2 | 23 | -1.625 | BD |
| 1 | 1 | 3 | -1 | 2 | 32 | -0.625 | ABD |
| -1 | -1 | 2 | 1 | 2 | 27 | -0.125 | CD |
| 1 | -1 | 3 | 1 | 2 | 35 | -0.625 | ACD |
| -1 | 1 | 4 | 1 | 2 | 26 | 0.625 | BCD |
| 1 | 1 | 1 | 1 | 2 | 33 | -0.375 | ABCD |

The effects have been calculated and shown. Test for significance of effects.

(5 marks)

# SOLUTIONS TO NUMERICAL PROBLEMS

1.

| d | -1.6 | -1.3 | 1.1 | 1.3 | -1 | -0.7 | -1.5 | -1.1 | -1.6 | -1.3 |
|---|---|---|---|---|---|---|---|---|---|---|
| dbar | -0.77 | | | | | | | | | |
| Sd | 1.0761 | | | | | | | | | |
| to | -2.147 | | | | | | | | | |
| t(0.05,9) | 2.2622 | | | | | | | | | |

There is insufficient evidence to claim that the two tests are different.

4.

| Effects | Last col | Invert | 1 | 2 | 3 | Invert | Pred | **Res1** | **Res2** |
|---|---|---|---|---|---|---|---|---|---|
| 10.194 | 81.55 | 0 | 0 | 0 | 96.4 | 17.2 | 2.15 | -0.95 | 0.25 |
| 10.163 | 40.65 | 0 | 0 | 96.4 | 64.6 | 148 | 18.5 | 1.1 | -1.1 |
| -0.263 | -1.05 | 0 | -25.8 | 0 | 148 | 64.6 | 8.075 | 0.325 | -0.175 |
| -6.188 | -24.75 | 0 | 122.2 | 64.6 | 17.2 | 96.4 | 12.05 | -0.65 | 0.55 |
| 0.1625 | 0 | -24.75 | 0 | 0 | 96.4 | 17.2 | 2.15 | 0.65 | 0.05 |
| -0.112 | 0 | -1.05 | 0 | 148 | 64.6 | 148 | 18.5 | -1.1 | 1.1 |
| -0.187 | 0 | 40.65 | 23.7 | 0 | 148 | 64.6 | 8.075 | -0.475 | 0.325 |
| 0.2375 | 0 | 81.55 | 40.9 | 17.2 | 17.2 | 96.4 | 12.05 | 0.45 | -0.35 |

5.

| | Var |
|---|---|
| | 4.5 |
| | 4.5 |
| | 12.5 |
| | 8 |
| | 2.9167 |
| | |
| Sp^2 | 5.4643 |
| sc | 1.4315 |

| | |
|---|---|
| Corner average | 40.375 |
| Centre average | 44.25 |
| Curvature | 3.875 |
| tC | 2.707 |
| tcrit | 2.3646 |

Hence the curvature is significant.

6.

| | |
|---|---|
| sw | 0.125 |
| tC | 11 |
| tcrit | 12.706 |

No evidence that C is significant

| | |
|---|---|
| A | 10.605 |
| B | -0.768 |
| AB | -0.154 |
| C | |
| AC | -0.768 |
| BC | 0.1537 |
| ABC | 0.7685 |

| | |
|---|---|
| sE | 0.8133 |
| tcrit | 2.4469 |

A appears to be significant, no evidence that other effects are significant.

PTO