# Design and Analysis of Experiments/Försöksplanering

**(KBT120, KKR031)**

**Thursday 22/8 2013 8:30-13:30 V**

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**Claes Niklasson will be available at ext 3027 (0731-574690) and will visit the examination room ca 11:00.**

**The examination results will be available for review 5/9**
**12:45 – 13:15 KRT sem. room.**

**Time for examination = 5 h**

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**Examination aids:**

**Textbook (Douglas C. Montgomery: Design and Analysis of Experiments) with notes. No calculation examples (in book or on paper) are allowed as aid.**

**All type of calculators are allowed.**

**Standard Math. Tables, TEFYMA table, Beta Mathematics Handbook or Handbook of Chemistry and Physics and Language dictionaries are accepted.**

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**Problem 1 (12 points)**

**At a Swedish company experiments have been performed in order to build up knowledge about the effect of different factors at pressure casting of brake cylinders in aluminium. The aim is to decrease the porosity, i.e. maximize the density.**

**The experiment variables were**
**A. Furnace temperature**
**B. Pressure**
**C. Cooling**
**D. Vacuum**
**E. Piston rate**
**F. Cycle time**

**One has conducted 16 runs divided in two blocks, where the interaction effects AB, AD, AF, BD and BE can be estimated without being confounded with each other. Remaining interaction effects can be neglected.**

**The evaluation gave the following effects**

$l_A = -0.005$ $l_B = 0.025$ $l_C = 0.01$ $l_D = 0.011$ $l_E = 0.021$ $l_F = 0.006$

$l_{AB} = 0.011$ $l_{AD} = 0.002$ $l_{AF} = 0.006$ $l_{BD} = -O.015$ $l_{BE} = O.012$

**The block effect is -0.006 and the mean value 2.7.**

**The total corrected sum of squares:** $\sum( y_i - \bar{y} )^2 = 77 \cdot 10^{-4}$

**Construct an ANOVA-table and estimate which effects are significant. Derive then the optimal combination (+1,-1) for the 6 variables and calculate the density in that point.**

**Earlier experiments have given an variance in repeated identical runs $s^2 = 2 \cdot 10^{-5}$ . Comment how you will use this information.**

**Problem 2 (8 points)**

**Suggest a design to estimate the parameters in a model with 3 controllable and 2 uncontrollable variables. Formulate a suitable model with controllable- and uncontrollable variables. Describe even how the variance for the prediction and the variance for the effect of uncontrollable variables can be estimated.**

**Problem 3 (12 points)**

**The article about ”Adiabatic humidification of air in a packed tower” describes the determination of the gas film heat transfer coefficient. The experiments were performed at four gas rates (factor A) and four liquid rates (factor B) with the following result:**

| A | B | | | |
|---|---|---|---|---|
| | 1(190) | 2(250) | 3(300) | 4(400) |
| 1(200) | 200 | 226 | 240 | 261 |
| 2(400) | 278 | 312 | 330 | 381 |
| 3(700) | 369 | 416 | 462 | 517 |
| 4(1100) | 500 | 575 | 645 | 733 |

**A: Analyse if liquid - and gas rates have a significant (99%) effect on the heat transfer coefficient.**

**B: Estimate if there is any significant difference between the liquid rates.**

**C: Comment the results in A and B.**

**Problem 4 (10 points)**

**On the basis of eight runs in a $2^3$ – factorial desgn with levels of the three variables ( $z_1$, $z_2$, $z_3$ ) according to the table below**

| $z_1$ | $z_2$ | $z_3$ | $x_1$ | $x_2$ | $x_3$ |
|---|---|---|---|---|---|
| 30 | 10 | 6 | -1 | -1 | -1 |
| 40 | 20 | 16 | 1 | 1 | 1 |

**one has determined the relationship between dependent variable and the original independent variables to**

$$\hat{y} = -1.15 + 0.05z_1 + 0.2z_2 + 0.1z_3$$

**One wishes to continue the analysis by adding new runs along the gradient in the normalized (scaled) and centred variable system with the start point in $x_1 = x_2 = x_3 = 0$. Physical and chemical limits involve that one can not step freely in the gradient direction. The restriction can be written**

$$4z_1 + 5z_2 + 6z_3 \leq 371$$

**In which point, ($z_1$ , $z_2$ , $z_3$), will the stepping in the gradient direction be stopped by the restriction?**

**Problem 5 (10 points)**

**A linear model $y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2$ with the parameter values $b=[50\ \ 10\ \ 5\ \ -5\ \ 3]^T$ is based on the following experimental design**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $x_1$ | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | 0 | 0 | 0 |
| $x_2$ | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | 0 | 0 | 0 |
| $x_3$ | -1 | -1 | -1 | -1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |

**The residual sum of squares is**

$$SS_E = \sum (y_i - \hat{y}_i)^2 = 8$$

**A: Calculate the confidence intervals (95%) for the regression coefficients.**

**B: Calculate the confidence interval (95%) for the prediction in the point [1 -1 1].**

**Problem 6 (8 points)**

**How should you decide what the reason is for large confidence intervals of the estimated parameters in a model? Suggest complementary experiments and a statistical analysis which can decide if the reason for large confidence intervals is bad experiments, bad model or bad experimental design.**