General Factorial Tutorial
(Part 2 – Making Factors Numeric)

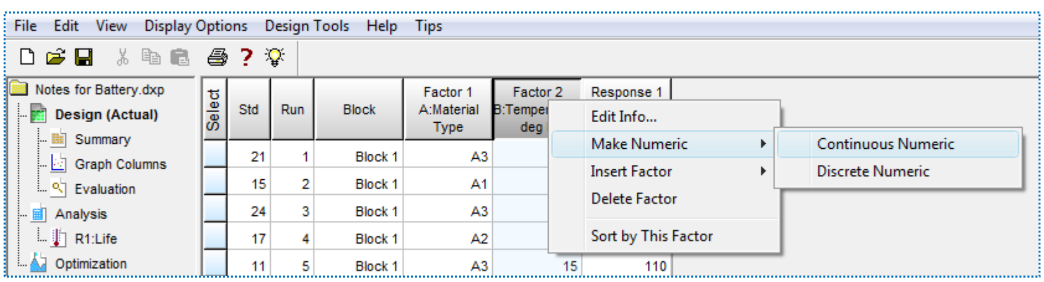
Continued – A Case Study on Battery Life

In the preceding, General Factorial Tutorial – Part 1, you treated all factors categorically. The main purpose of Part 2 of this tutorial is to illustrate some of the functions built into Design-Expert that can be used to make effects graphs better fit the type of data we're dealing with, in addition to making the results easier to interpret and understand. (We've already said that Montgomery's classic battery experiment could have been handled by using the Response Surface tab in Design-Expert® software and constructing a one-factor design on temperature, with the addition of one categorical factor at three levels for the material type. Never fear, we'll cover response surface methods like this from the ground up later in the Response Surface Tutorials.) But to demonstrate the flexibility of Design-Expert, let's see how you can make the shift from categoric to numeric in Design-Expert after-the-fact, even within the context of a general factorial design.

To get started, let's re-open the file named **Battery.dxp** saved earlier (if it is not already open). Then, click the Design node for the battery data from Part One.

Changing a Factor from Categoric to Numeric

Place your cursor on the **B:Temperature** factor column heading, right click, and move your cursor to **Make Numeric** and then **Continuous Numeric**. (The "discrete" option could also work in this case. It works well for numeric factors that for convenience-sake must be set at specific levels. For example, imagine that the testing chamber for the batteries has only three settings – 15, 70 and 125.)

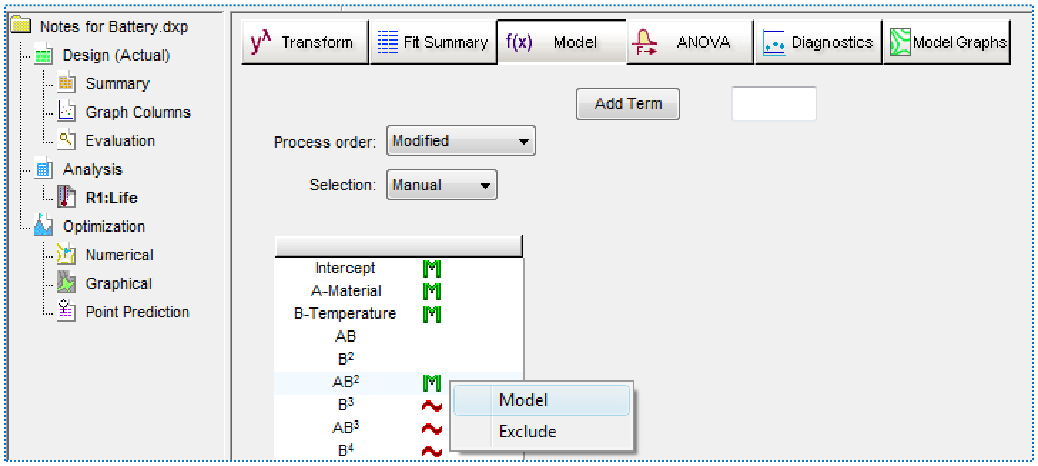


Options for editing a factor

The software pops up a warning not to do this if the factor really is categorical. To acknowledge it and move on, click the **OK** button below message.

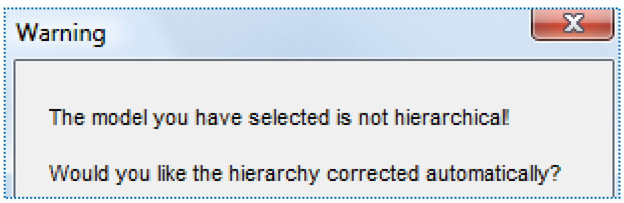
Re-Analyzing the Results

To re-analyze your data, click the analysis node labeled **Life**. Then click the ***Model*** button. When you designated a factor being numeric, Design-Expert automatically shifted to fitting a polynomial, such as those used for response surface methods. To model possible non-linearity of the response as a function temperature (factor B), double-click the **AB^2** term, or via a right click and add it to the **Model** as shown below. (Squared terms capture curvature.)



Model selection screen

Click the ***ANOVA*** button. You will get a warning about hierarchy.



Hierarchy warning

This warning arises because you chose a higher order term without support by parent terms, in this case: AB and B^2. Click **Yes** and move on. (For details, search out the topic on "Model Hierarchy Check" in the Help System.)

The ANOVA report now displays in the view (annotated or not) that you used last. By comparing this output with the ANOVA done in Part One, observe that the lines for the model and residual come out the same, but the terms involving B differ. In Part One we treated factor B (temperature) categorically, although in an ordinal manner. Now that this factor is recognized explicitly as numeric, what was the effect of B is now broken down to two model terms – B and B^2, and AB becomes AB plus AB^2.

Response 1 Life

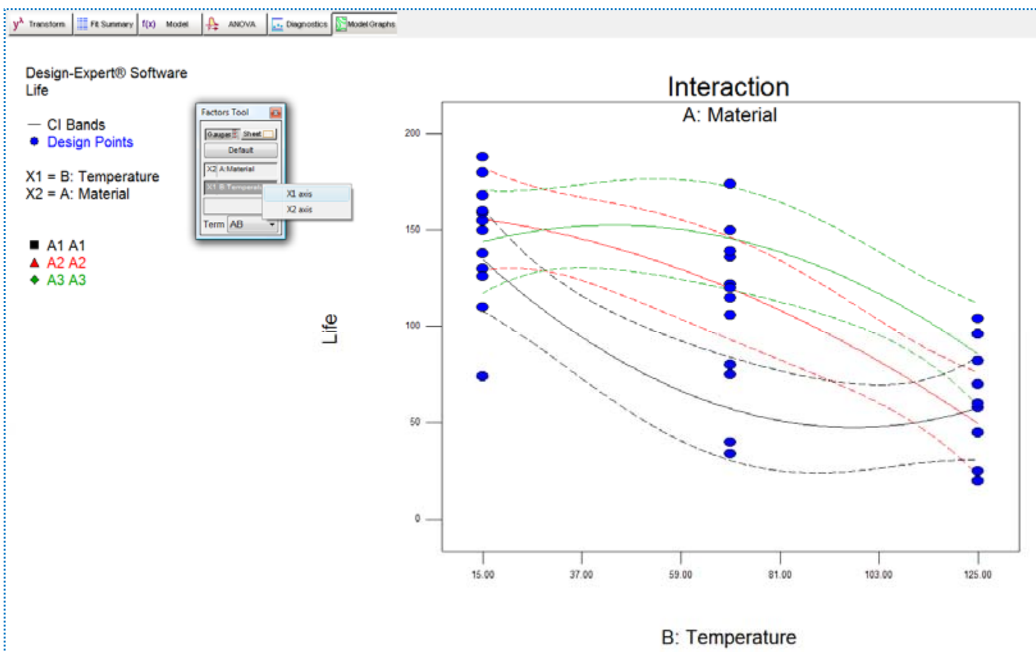
ANOVA for Response Surface Reduced Cubic Model

Analysis of variance table [Classical sum of squares - Type II]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	59416.22	8	7427.03	11.00	< 0.0001
A-Material	*10683.72*	*2*	*5341.86*	*7.91*	*0.0020*
B-Temperat	*39042.67*	*1*	*39042.67*	*57.82*	*< 0.0001*
AB	*2315.08*	*2*	*1157.54*	*1.71*	*0.1991*
B^2	*76.06*	*1*	*76.06*	*0.11*	*0.7398*
AB^2	*7298.69*	*2*	*3649.35*	*5.40*	*0.0106*
Pure Error	18230.75	27	675.21		
Cor Total	77646.97	35			

ANOVA output

The whole purpose of this exercise is to make a better looking effects graph. Let's see what this looks like by clicking the ***Model Graphs*** button. Go to the floating **Factors Tool**, right-click **B** (Temperature) and change it to the **X1 Axis**.



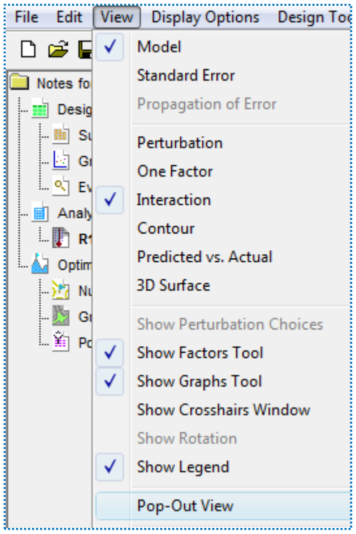
Viewing the interaction with temperature on X-axis

You now have a plot characterizing the data from Part One of this ongoing case study, except that the above lines are now continuous with temperature, whereas in Part One they were displayed as discrete (categorical) segments. Notice that the curves by temperature (modeled by B^2) depend on the type of material (A). This provides graphical verification of the significance of the AB^2 term in the model. (The dotted lines are the confidence bands. If they cause you more trouble than you feel they're worth for conveying the uncertainty in fitting, feel free to change Graph Preferences to take these off – this option is provided on the XY Graphs tab.)

The conclusions remain the same as before: Material A3 will maximize battery life with minimum variation in ambient temperature. However, by treating temperature numerically, predictions can be made at values between those tested. Of course, these findings are subject to confirmation tests.

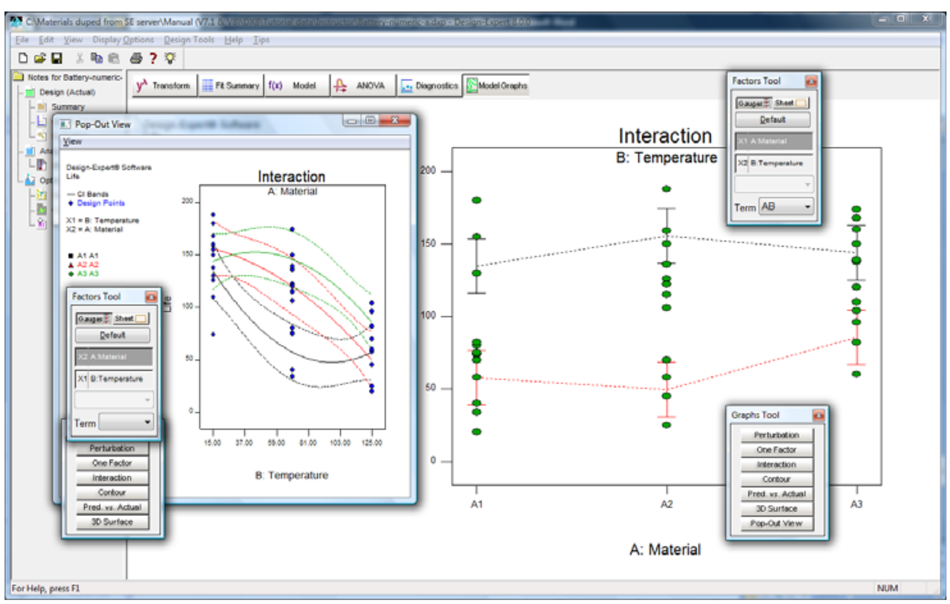
Postscript: Demo of "Pop out" View

Before exiting Design-Expert, give this a try: **View, Pop out View** as shown below. (New to DX8 – simply click **Pop out View** on the floating Graphs Tool.)



Pop out View

This pushes the current graph out of its fixed Windows pane into a 'clone' that floats around on your screen. Now on the **Factors Tool** <u>right click</u> on **A** (Material) and return it to the **X1 Axis**. Then do an Alt-Tab to bring back the clone of the previous view back on your current window.



Two ways of viewing the battery life results

You can present Design-Expert outputs both ways for your audience:

- Curves for each material as a function of temperature on the X1 axis, or
- Two temperature lines connected to the three discrete materials as X1.

Another way to capture alternative graphs is to copy and paste them into a word-processor, spreadsheet, or presentation program. Then you can add annotations and explanations for reporting purposes.