Chapter 264

Response Surface Designs

Introduction

Response-surface designs are the only designs provided that allow for more than two levels. There are two general types of response-surface designs. The central-composite designs give five levels to each factor. The Box-Behnken designs give three levels to each factor.

The Central-Composite designs build upon the two-level factorial designs by adding a few center points and star points. A factor's five values are: $-a$, -1, 0, 1, and a. The value of a is determined by the number of factors in such a way that the resulting design is orthogonal. For example, if you are going to use either four or five factors, the value of a is 2.00.

The actual values of the levels are determined from these five values as follows:

1. The low-level value is assigned to -1.

2. The high-level value is assigned to 1.

3. The average of these two values is assigned to 0.

4. The values of $-a$ and a are used to find the minimum and the maximum values.

For example, suppose we entered 50 for the low-level and 60 for the high level. Further, suppose there were four factors in the experiment. The levels would be

Coded Level	Actual Level
$-a$	45
-1	50
0	55
1	60
a	65

The values of a depend on the number of factors in the design:

Factors	Value of a
2	1.41
3	1.73
4	2.00
5	2.00
6	2.24

The Box-Behnken designs have two differences from the central-composite designs. First, they usually use fewer runs. Second, they only use three levels while the central-composite designs use five.

The actual values of the levels are determined in the same manner as the central-composite designs, except that the value of a is ignored.

Example 1 – Response Surface Design

This section presents an example of how to generate an experimental design using this program. **CAUTION: since the purpose of this routine is to generate (not analyze) data, you should always begin with an empty dataset.**

In this example, we will show you how to generate a three-factor central composite design with blocks.

Setup

To run this example, complete the following steps:

1   Specify the Response Surface Designs procedure options

- Find and open the **Response Surface Designs** procedure using the menus or the Procedure Navigator.
- The settings for this example are listed below and are stored in the **Example 1** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab
_____

Design Type...**Central-Composite**
Sort Order..**Standard**
Factor 1 ....**-1 1**
Factor 2 ....**-1 1**
Factor 3 ....**-1 1**
Store the Design Data in the Data Table ....**Checked**

---

2   Run the procedure

- Click the **Run** button to perform the calculations and generate the output.

Three-Factor Response-Surface Design

Experimental Design: Central-Composite

Row	Block	Factor 1	Factor 2	Factor 3
1	1	-1	-1	-1
2	1	1	-1	-1
3	1	-1	1	-1
4	1	1	1	-1
5	1	-1	-1	1
6	1	1	-1	1
7	1	-1	1	1
8	1	1	1	1
9	1	0	0	0
10	1	0	0	0
11	1	0	0	0
12	2	-1.73	0	0
13	2	1.73	0	0
14	2	0	-1.73	0
15	2	0	1.73	0
16	2	0	0	-1.73
17	2	0	0	1.73
18	2	0	0	0
19	2	0	0	0
20	2	0	0	0

The block and factor values were also written to the Data Table.

Note that there are three replicates of the center points in each block. Note the star points represented by -1.73 and 1.73.