RESPONSE SURFACE DESIGNS UNDER SPLIT- PLOT STRUCTURE

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ABSTRACT

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Response Surface Methodology (RSM) is a set of statistical and mathematical techniques that are useful for designing, formulating, developing, analyzing and optimizing the process under study. RSM is usually a sequential procedure. The objective is to provide adequate relationship between the several input variables that influence the response of interest and to locate optimum response of the process. It is extensively applied in a wide variety of areas; Agricultural and Biological sciences, Industries, Food Science, Pharmaceutical, Analytical Chemistry, Biotechnology and Environmental Studies.

In literature there are many different second-order designs available. Two very useful and popular designs are Central Composite Designs (CCDs) and Box-Behnken Designs (BBDs). Zhang et al. (2011) constructed small BBDs with less number of runs. All the designs are highly efficient and satisfy the orthogonal properties. In literature, apart from BBDs, numerous three-level second-order response surface designs are also available.

In many industrial experiments we often encounter situations where two types of factors exist; Hard-to-Change (HTC) factors and Easy-to-Change (ETC) factors. In such cases split-plot design structure is used. HTC factors are randomly applied to whole-plots and ETC factors are randomly applied to sub-plots. These designs can be balanced or unbalanced. For the study of split-plot designs, various optimality criteria are available in the literature. Most frequently used is D-optimality criterion.
When all experimental runs cannot be performed under homogeneous conditions, blocking can be used to increase the power for testing the treatment effects. Orthogonal blocking provides the same estimate of the model parameters as would have been obtained had there been no blocking. Dey (2009) studied the orthogonal blocking of three-level second-order response surface designs. Wang et al. (2009) gave the conditions for orthogonal blocking for second-order response surface designs under split-plot structure.

Usually response surface experiments are conducted considering all factors as quantitative in nature. There are situations where experiment is needed to be conducted with at least one qualitative factor. To study the response of experiments involving both qualitative and quantitative factors, the qualitative factors must be involved in the model and the design. This aspect has been considered, among others, by Draper and John (1988), Wu and Ding (1998), Aggarwal et al. (2000) and Lee and Huang (2011).

Here, we have studied the response surface designs under split-plot structure for the different situations. In Chapter 2, we have constructed second-order split-plot designs involving both quantitative and qualitative factors using the CUBE and STAR designs given by Draper and John (1998). We have discussed two approaches for the construction of the designs. In the first approach, we have added one qualitative factor to the design and in the second approach one of the HTC factors is considered as qualitative factor. The D-optimal value has been used for selection of the design. The balanced and unbalanced designs, given by Parker et al. (2006, 2007a, 2007b), are used to construct second-order split-plot designs involving both qualitative and
quantitative factors are given in Chapter 3. The designs having highest D-optimal values are selected. In both the Chapters, we have considered only two levels of the qualitative factor.

In Chapter 4, some new three-level second-order split-plot designs are constructed using screening designs, given by Jones and Nachtsheim (2011), and three-level orthogonal arrays. These screening designs form the first order designs to which three-level orthogonal array is augmented to form second-order designs. The D-optimal values and relative efficiencies of these designs with respect to VKM BBDs, given by Parker et al. (2006, 2007b), are also computed for different variance ratios. In Chapter 5, we have constructed balanced three-level second-order split-plot designs using the designs given by Dey (2009) and unbalanced three-level second-order split-plot designs using the designs given by Zhang et al. (2011). We have then discussed the orthogonal blocking of these designs.

Chapter 6 is based on constructing the split-plot designs, involving two HTC and four ETC factors using 24-run Hadamard matrices and the relative efficiency ratios of these designs are then computed with respect to 24-run regular design, developed by Kowalski (2002), and 32-run regular design. 20-run Hadamard matrices are used for constructing the split-plot designs involving two HTC and two ETC and two HTC and three ETC factors, in Chapter 7. D-optimal values of these designs are then obtained for different variance ratios.