



Blocked two-level semifoldover designs



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ABSTRACT

Foldover design is a commonly used technique that is obtained by adding another fraction to an initial fractional factorial design. Because such added designs require the same run size as the initial design, semifoldover designs that consist of half of a foldover fraction have been investigated in the recent literature for regular two-level fractional factorial designs. As the initial design and the follow-up semifoldover design are usually conducted at different stages, it is important to consider a block factor reflecting this effect. This paper studies the impact of the block factor on the semifoldover of 2^{k-p} designs. We first propose a method for obtaining the equivalent semifoldover plans. Then the properties and the structures of blocked semifoldover designs are explored. The optimal blocked semifoldover designs for 16 and 32 runs are obtained and tabulated for practical use.

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1. Introduction

Two-level fractional factorial designs are commonly used in practice. Compared to full factorial designs, the run size savings of them can be substantial. This attractive feature comes at the price of aliasing of factorial effects. To resolve such ambiguities, a standard follow-up strategy involves adding a second fraction, called a foldover design, which was obtained by reversing the signs of some columns of the initial design. (See, for example, the textbooks of Box et al., 1978; Kutner et al., 2005.) Foldover designs have received increasing attention in recent years. In particular, optimal foldover plans, which aim to de-alias the maximum number of confounded effects, have been developed for both regular (Li and Mee, 2002; Li and Lin, 2003) and non-regular designs (Li et al., 2003).

One limitation of the foldover strategy is that it requires twice as many runs as the initial design. In Barnett et al. (1997), they described a follow-up strategy named as *semifolding* by adding half of a foldover fraction. Mee and Peralta (2000) and John (2000) studied semifoldover designs and showed that, in many cases, a semifoldover design can de-alias as many confounded main effects or two-factor interactions as the corresponding foldover design. John (2000) also investigated other partial foldover designs. Since for each initial design, one can get many semifoldover designs, Huang et al. (2008) searched optimal semifoldover designs using the criterion of de-aliasing maximum number of confounded main effects and two-factor interactions. Balakrishnan and Yang (2009) and Edwards (2011) explored semifolding non-regular designs.

In practice, follow-up experiments such as foldover and semifoldover designs are typically conducted at a later time than the initial design. Thus, it is important to include a block factor and study its impact. The blocked foldover designs

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have been discussed previously in the literature. Ye and Li (2003) showed that the inclusion of the block factor does not change the ranking of the foldover designs in terms of the aberration criterion. Li and Jacroux (2007) studied optimal foldover plans for blocked 2^{k-p} fractional factorial designs. Ai et al. (2010) considered optimal blocking and foldover plans for regular two-level designs. Ou et al. (2011) extended the work to non-regular designs. For semifoldover designs, all of the existing studies focused on unblocked designs. The objective of this article is to bridge the gap between optimal semifoldover designs and blocked designs. We consider blocked semifoldovers for regular two-level fractional factorial designs. Throughout this article, we assume that (i) the interactions involving three or more treatment factors are negligible and (ii) the interactions between the block factor and the treatment factors are negligible. (See Wu and Hamada, 2000 for the discussion of this assumption.) As in previous studies on optimal foldover and semifoldover designs, we investigate the optimality of designs in terms of the number of confounded main effects and two-factor interactions that can be de-aliased by the addition of a semifoldover design.

The remainder of the paper is organized as follows. In Section 2, we classify the equivalent semifoldover designs and then provide a way to obtain the equivalent semifoldover plans. Some properties of blocked semifoldover designs are considered in Section 3. It is shown that, in some cases, the effects that can be de-aliased in an unblocked semifoldover design can also be de-aliased in the corresponding blocked semifoldover design. In Section 4, the optimal blocked semifoldover designs for 16 and 32 runs in Chen et al. (1993) are searched and tabulated. The comparisons between the optimal blocked semifoldover designs and the optimal unblocked semifoldover designs in Huang et al. (2008) are made. Some concluding remarks are given in Section 5.

2. Semifoldover designs

Consider a two-level fractional factorial design with n runs and k factors, with levels being denoted by ± 1 . Following Li and Lin (2003), we denote a foldover plan γ as a collection of r ($r \leq k$) columns whose signs are to be reversed in the foldover design. (Reversing the sign of a column means reversing the signs of all elements in that column.) A foldover design is fully defined by a foldover plan. However, in order to obtain a semifoldover design, we need an additional step called *subsetting*. Consider an 8-run 2^{4-1} design defined by $D=ABC$, which is shown in Table 1. After folding over on column C, two semifoldover designs can be constructed based on the sign of column D. This procedure is called subsetting on D, abbreviated as $ss=D$. In Table 1, runs 9–12 correspond to half of the foldover design whose elements of D equal +1, and the corresponding design is denoted as: $\gamma=\{C\}$, $ss=D+$. Similarly, design of runs 9'–12' is constructed by $\gamma=\{C\}$, $ss=D-$.

Table 1 shows two semifoldover designs obtained by subsetting on a main effect. In general, subsetting can be conducted on either a main effect or an interaction, which we denote as X. For a given foldover plan, a semifoldover can be constructed by either $ss=X+$ or $ss=X-$, corresponding to runs of the foldover design whose elements of X equal +1 or -1, respectively. We call the combination of the initial n -run design and the newly added $n/2$ -run semifoldover a *combined semifoldover design*. (In the discussions of blocked designs, we will often omit the word “combined” to avoid the use of long names. That is, the blocked semifoldover design is usually referred to the blocked combined semifoldover design.)

In this paper we focus on the regular two-level fractional factorial designs. A regular 2^{n-p} design is defined by p generators, which involve p defining words. The group formed by these defining words constitutes a *defining relation*, and each term in the defining relation is called a *word*. Consider, for example, a 2^{6-2} design with generators $E=ABC$ and $F=BCD$. The two defining words are $ABCE$ and $BCDF$. The defining relation of the design is $I=ABCE=BCDF=ADEF$, and there are four words: I (whose elements are all 1 s), $ABCE$, $BCDF$, and $ADEF$.

Table 1

Illustration of two semifoldover designs. (Runs 9–12 are defined by $\gamma=\{C\}$, $ss=D+$; Runs 9'–12' are defined by $\gamma=\{C\}$, $ss=D-$.)

Run	Block	A	B	C	D = ABC
1	1	-1	-1	-1	-1
2	1	1	-1	-1	1
3	1	-1	1	-1	1
4	1	1	1	-1	-1
5	1	-1	-1	1	1
6	1	1	-1	1	-1
7	1	-1	1	1	-1
8	1	1	1	1	1
9	-1	1	-1	1	1
10	-1	-1	1	1	1
11	-1	-1	-1	-1	1
12	-1	1	1	-1	1
9'	-1	-1	-1	1	-1
10'	-1	1	1	1	-1
11'	-1	1	-1	-1	-1
12'	-1	-1	1	-1	-1

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