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Research Article

Comparison JONES-DSD and [a,b] Analysis at the Real Design Stage for Optimizing

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Abstract

JONES:DSD[1)] (C+, C-, C0) designs are known to prevent two-factor product terms and squared terms from confounding linear terms. However, the number of experiments required is roughly twice that of the conference (C) matrices alone. Therefore, when comparing the DSD design with the C matrices and [a,b] analysis[2)] using the same layout (Power supply[3)] circuit: 3 levels, 6 factors), the number of experiments was roughly the same. The response (output voltage: larger is better) characteristics were 21.11 and 31.69, respectively, and the latter (C matrices and [a, b] analysis) was superior, so we report this. Furthermore, the level combination response for the maximum factor effect of DSD was below the maximum value of the DSD response.

Keywords: Conference Matrices; DSD; Optimizing; [a,b] Analysis; Orthgonality

Introduction

DSD design is an acronym for Definitive Screening Design 1) and is translated as a definitive selection method. It assumes full column allocation of three-level factors, and definitive refers to a matrix in which the largest squared term after the linear term and the two-factor product term (interaction) are not confounded (they overlap and cannot be separated). The matrix that achieves this is called a conference matrix (abbreviated as C), and is written as [C+, C-, C0].

0	1	1	1
1	0	−1	1
1	1	0	−1
1	−1	1	0

Table 1: Shows the smallest conference matrix, C_4 ($2^1 3^3$).

The conference matrix is a square matrix whose diagonal is "0" and the other sides are "-1, +1", and the sum of the products between columns is "0".

DSD matrix generation and component confounding

The DSD generation process and its component confounding are shown below. Table 1 is C_4+, the C_4 matrix is multiplied by (-1) to obtain C_4-, and the central condition (second level) is C0, as shown in Table 2. The factor names are A,B,C,D.

DSD	No	A	B	C	D
C4+	1	0	1	1	1
	'2	1	0	-1	1
	3	1	1	0	-1
	4	1	-1	1	0
C4-	5	0	-1	-1	-1
	6	-1	0	1	-1
	7	-1	-1	0	1
	8	-1	1	-1	0
C0	9	0	0	0	0

Table 2: C_4: DSD Design.

Next, squared and product terms are generated from the linear terms and shown in Table 3.

Correlation coefficients are calculated from the coefficient matrix in Table 3 and shown in Table 4.

The process of combining positive and negative values of a matrix to create a matrix that does not confound the linear terms with squared and multiplied terms is called a “fold-over design”.

A	B	C	D	A^	B^	C^	D^	AB	AC	AD	BC	BD	CD
0	1	1	1	0	1	1	1	0	0	0	1	1	1
1	0	-1	1	1	0	1	1	0	-1	1	0	0	-1
1	1	0	-1	1	1	0	1	1	0	-1	0	-1	0
1	-1	1	0	1	1	1	0	-1	1	0	-1	0	0
0	-1	-1	-1	0	1	1	1	0	0	0	1	1	1
-1	0	1	-1	1	0	1	1	0	-1	1	0	0	-1
-1	-1	0	1	1	1	0	1	1	0	-1	0	-1	0
-1	1	-1	0	1	1	1	0	-1	1	0	-1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3: C_4: Linear, Squared, and Product Terms.

Term	A	B	C	D	A^	B^	C^	D^	AB	AC	AD	BC	BD	CD
A	1													
B	0	1												
C	0	0	1											
D	0	0	0	1										
A^	0	0	0	0	1									
B^	0	0	0	0	0.00	1								
C^	0	0	0	0	0.00	0.00	1							
D^	0	0	0	0	0.00	0.00	0.00	1						
AB	0	0	0	0	0.00	0.00	-0.71	0.71	1					
AC	0	0	0	0	0.00	0.71	0.00	-0.71	-0.50	1				
AD	0	0	0	0	0.00	-0.71	0.71	0.00	-0.50	-0.50	1			
BC	0	0	0	0	-0.71	0.00	0.00	0.71	0.50	-0.50	0.00	1		
BD	0	0	0	0	-0.71	0.00	0.71	0.00	-0.50	0.00	0.50	0.50	1	
CD	0	0	0	0	-0.71	0.71	0.00	0.00	0.00	0.50	-0.50	0.50	0.50	1

Table 4: Correlation Coefficients.

Term	A	B	C	D	A^	B^	C^	D^	AB	AC	AD	BC	BD	CD
A	1													
B	-0.33	1												
C	-0.33	-0.07	1											
D	-0.33	-0.07	-0.07	1										
A^	1.00	-0.33	-0.33	-0.33	1									
B^	0.17	0.22	0.76	-0.33	0.17	1								
C^	0.17	-0.33	0.22	0.76	0.17	0.17	1							
D^	0.58	0.71	-0.71	0.00	0.58	0.00	0.00	1						
AB	0.00	0.85	-0.42	-0.42	0.00	0.00	-0.65	0.71	1					
AC	0.00	-0.42	0.85	-0.42	0.00	0.65	0.00	-0.71	-0.50	1				
AD	0.00	-0.42	-0.42	0.85	0.00	-0.65	0.65	0.00	-0.50	-0.50	1			
BC	-0.65	0.85	0.00	0.42	-0.65	0.00	0.00	0.58	0.50	-0.50	0.00	1		
BD	-0.65	0.00	0.42	0.85	-0.65	0.00	0.65	-0.58	-0.50	0.00	0.50	0.500	1	
CD	-0.65	0.42	0.85	0.00	-0.65	0.65	0.00	-0.58	0.00	0.50	-0.50	0.500	0.50	1

Table 5: C_4: Correlation coefficients excluding [C_4-] from DSD.

The squared and product terms for the linear terms on the left (top) are zero.

Table 5 shows the correlation coefficients excluding [C_4-] from C_4: DSD. The linear terms are confounded by the squared and product terms.

Regression Analysis of the DSD Design [Whole and Partial] and [a, b] Analyses2)

Table 2 of Jones (2011) [1)] shows C_6-type DSD (13 runs). This is shown in Table 6. The top row of Table 6 shows DSD, the middle row shows C_6+, and the bottom row shows C_6+.

Regression coefficients (Table 7) were obtained from regression analysis for the top, middle, and bottom of Table 6, and the factor effects, with the intercept at the second level minus the regression coefficient of each factor to obtain the first level, plus the third level, are shown in Figure 1. The regression coefficient for DSD is the average of C_6+ and C_6-. Note that x6 in the middle and bottom rows of Table 6 has two levels. In Figure 1, x1 to x5 in Table 6 are compared as ABCDE. The larger the characteristic (y), the better.

JONES DSD data(page*5)							
DSD	x1	x2	x3	x4	x5	x6	y
1	0	1	-1	-1	-1	-1	21.04
2	0	-1	1	1	1	1	10.48
3	1	0	-1	1	1	-1	17.89
4	-1	0	1	-1	-1	1	10.07
5	-1	-1	0	1	-1	-1	7.74
6	1	1	0	-1	1	1	21.01
7	-1	1	1	0	1	-1	16.53
8	1	-1	-1	0	-1	1	20.38
9	1	-1	1	-1	0	-1	8.62
10	-1	1	-1	1	0	1	7.8
11	1	1	1	1	-1	0	23.56
12	-1	-1	-1	-1	1	0	15.24
13	0	0	0	0	0	0	19.91
C6+	x1	x2	x3	x4	x5	x6	y
1	0	1	-1	-1	-1	-1	21.04
3	1	0	-1	1	1	-1	17.89
5	-1	-1	0	1	-1	-1	7.74
7	-1	1	1	0	1	-1	16.53
9	1	-1	1	-1	0	-1	8.62
11	1	1	1	1	-1	0	23.56
13	0	0	0	0	0	0	19.91
C6-	x1	x2	x3	x4	x5	x6	y
2	0	-1	王冠	1	1	1	10.48
6	1	1	0	-1	1	1	21.01
8	1	-1	-1	0	-1	1	20.38
10	-1	1	-1	1	0	1	7.8
12	-1	-1	-1	-1	1	0	15.24
13	0	0	0	0	0	0	19.91

Table 6: C_6-type DSD in Table 2 of Jones (2011).

Suject	SSD	C6+	C6-
Regression Statistics			
Multiple R	0.738385	1	1
rSequare R2	0.545213	1	1
Adjusted R2	0.090426	65535	65535
Standard error	5.489250	0	0
Qvservatons	13	7	7
ANOVA			
Term	df	df	df
Regression	6	6	6
Error	6	0	0
Sum	12	6	6
Term	Coefficent	Coefficent	Coefficent
Intercept	15.40538462	19.91	19.91
x1 A	3.408	1.178	5.638
x2 B	2.748	4.972	0.524
x3 C	-1.309	-2.026	-0.592
x4 D	-0.851	-0.076	-1.626
x5 E	-0.164	0.398	-0.726
x6 F	-0.208	5.546	-5.962

Table 7: Regression analysis.

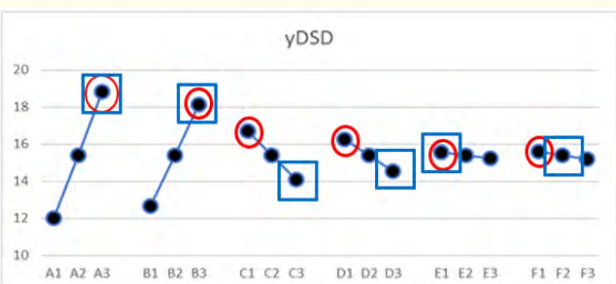

Figure 1: Factor Effects.

The maximum combination (b) of factor effects in Figure 1 is $A_3B_3C_1D_1E_1F_1$[|]. The maximum DSD value No. 11 (a) is A_3B_3C3D$_3E_1F_2$[y]. There are differences in the CDF levels in (a) and (b), indicating an interaction between the study subjects. This type of diagnosis is an [a.b] analysis. Figures 2 and 3 show the addition of C_6+ and C_6-.

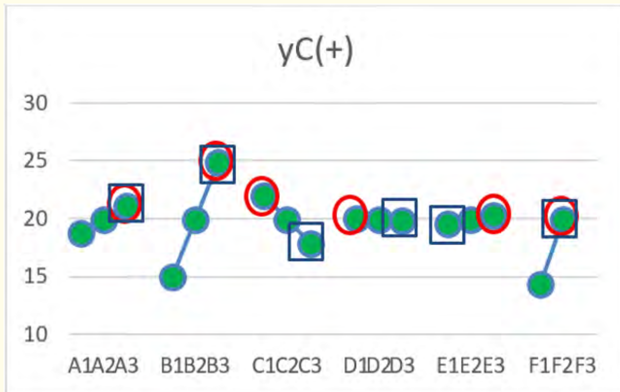

Figure 2: Factorial effects of C6+.

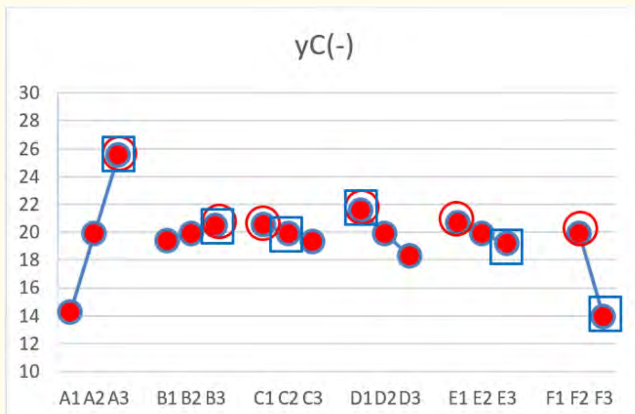

Figure 3: Factorial effects of C6-.

Table 8 shows the results of the [a,b] analysis of Figures 1, 2, and 3 based on the [□,○] agreement. In the [a,b] analysis of all matrices, there was a [□,○] disagreement of the half factors. DSD nullifies the confounding of the quadratic term with the linear term, but higher-order terms are present.

DSD at viewpoint from a design experiments

Design is defined as rearranging design constants to increase response or reduce variability. Linear factors, which change

Matrices	Trials	□=○	□≠○
DSD	13	A,B,E	C,D,F
C6+	7	A,B,F	C,D,E
C6-	7	A,B,D	C,E,F

Table 8: Summary of [a,b] analysis of Figures 1, 2, and 3.

response in proportion to changes in level, are prioritized in the design. Factors whose response changes nonlinearly with changes in level are difficult to incorporate into the design. Conversely, if the maximum level of a series of experiments is (a:□) and the maximum level of the factor effect is (b:○), factors that match (□= ○) can be assumed to be linear (main effect). Factors that do not match (□≠○) can be assumed to be nonlinear (affected by multi-factor interactions). In the next experimental plan, the linear factor levels are set to improve response.

The DSD design is a matrix in which the linear terms of the regression coefficients are not confounded with "squared terms and product terms" (nonlinear effects between two factors), but an [a, b] analysis can be used to diagnose up to which columns these linearized model equations hold and which do not. According to this, there is no difference in the level trends of the factor effects of the DSD in Figure 1 and C_6+ in Figure 2, so C_6- is unnecessary. Below, we will verify this using the power supply circuit.

Comparison of DSD Planning and C matrix optimization by power supply circuit[3)]

Applied power supply circuit and equations

The applied power supply circuit (5) and its equations are shown in Figure 4 and Figure 5, respectively.

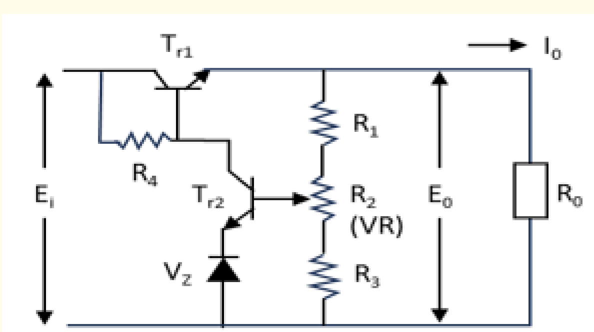

Figure 4: Applied electrical circuit.

$$E_0 = (P_2+P_3)/P_1$$

$$P_1 = \frac{(R_1+R_2/2)(1+T_{r1})+R_4\cdot T_{r2}(1+T_{r1})+R_4}{(R_1+R_2/2)(1+T_{r1})}$$

$$P_2 = E_i - V_{BE1} + \frac{(V_{BE2}+V_Z)\cdot T_{r2}\cdot R_4}{R_1+R_2/2} + \frac{(V_{BE2}+V_Z)\cdot T_{r2}\cdot R_4}{R_3+R_2/2}$$

$$P_3 = \frac{V_{BE2}\cdot R_4+V_Z\cdot R_4 - I_0\cdot R_4(R_1+R_2/2)}{(R_1+R_2/2)(1+T_{r1})}$$

※E_i=20V、 I_0=0〜0.8A、 $V_{BE1}=V_{BE2}=V_Z$=0.6V一定

Figure 5: Power supply circuit equation.

Factors and levels used

The allocation was based on six factors with three levels, as shown in Table 9.

Factor	R1(Ω)	R2(Ω)	R3(Ω)	R4(Ω)	Tr1	Tr2
1	6500	330	900	250	20	60
2	11000	560	1500	420	35	100
3	18500	950	2500	710	60	170

Table 9: Factors and Levels Used.

Implementation of the DSD plan

- Applied C_6 (3^6) Single Unit 6)
- Applied C_6 (3^6) in Table 9 is shown in Table 10.

0	1	1	-1	1	1
1	0	1	1	-1	1
1	1	0	1	1	-1
-1	1	1	0	-1	-1
1	-1	1	-1	0	-1
1	1	-1	-1	-1	0

Table 10: Applied C6 (36).

DSD Consisting of C_6 in Table 10, Results, and Analysis

The DSD is shown in Table 11 as {C_6+, C_6-, Co}. The regression analysis is shown in Table 12, and the factorial effect diagram is shown in Figure 6.

DSD	R1(Ω)	R2(Ω)	R3(Ω)	R4(Ω)	Tr1	Tr2	N1	N2	SN	y
1	0	1	1	-1	1	1	6.084	11.463	6.832	8.774
2	1	0	1	1	-1	1	4.981	13.278	2.837	9.129
3	1	1	0	1	1	-1	8.965	17.918	6.029	13.441
4	-1	1	1	0	-1	-1	1.917	10.020	-2.328	5.968
5	1	-1	1	-1	0	-1	8.388	18.259	4.974	13.324
6	1	1	-1	-1	-1	0	10.898	21.373	6.279	16.135
7	0	-1	-1	1	-1	-1	6.442	18.049	2.371	12.246
8	-1	0	-1	-1	1	-1	8.094	14.760	7.305	11.427
9	-1	-1	0	-1	-1	1	4.932	10.117	5.697	7.525
10	1	-1	-1	0	1	1	17.076	25.151	11.196	21.114
11	-1	1	-1	1	0	1	5.779	9.711	8.610	7.745
12	-1	-1	1	1	1	0	3.624	7.172	6.158	5.398
13	0	0	0	0	0	0	6.794	13.934	5.698	10.364

Table 11: {C6+, C6-, Co}.

Regression Statistics			Regression Statistics	
Multiple R	0.96420857		Multiple R	1
R Sqre	0.92969816		R Sqre	1
Ajstated R sqar	0.85939631		Ajstated R sqar	65535
Standard error	1.21981521		Standard error	0
Ovservation	13		Ovservation	7
ANOVA			ANOVA	
DSDY	Freedum		DSDY	Freedum
Regression	6		Regression	6
Stndard Residua	6		Stndard Residu	0
Total	12		Total	6
DSDY	Coeffcient		C+Y	Coeffcient
Intercept	5.5122287		*Intercept*	5.6979347
R1 (Ω)	0.58738648		R1 (Ω)	1.07072552
R2 (Ω)	-0.4973613		R2 (Ω)	-1.05108457
R3 (Ω)	-1.7288536		R3 (Ω)	-2.21153128
R4 (Ω)	-0.5081837		R4 (Ω)	-0.70434406
Tr1	2.26653228		Tr1	2.35439724
Tr2	1.68213439		Tr2	1.33833313

Table 12: Regression analysis.

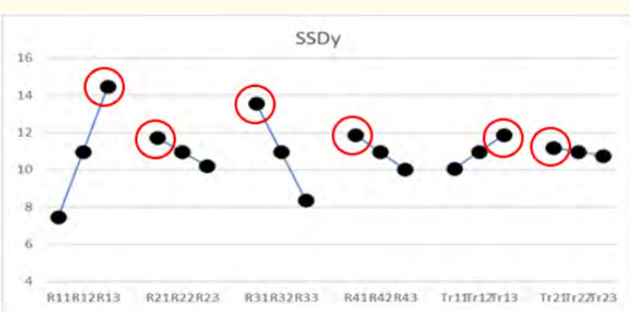

Figure 6: Factorial Effects of SSDy.

DSD factor effect diagram and optimal solution

The intercept of SSDy was set to the second level, and the third level was determined by subtracting the regression coefficient and adding the first level. The optimal conditions are shown in Table 13. The optimal response was 19.43. The DSD linearization was insufficient, and the maximum value of 21.11 in the DSD experiment could not be exceeded. Even when DSD was performed to avoid the confounding of squared and product terms with linear terms, the predictive accuracy of the optimal conditions did not increase. If the interactions between multiple factors were "zero," linearization would be complete, and the response would match the maximum value of 21.33 across all combinations. DSD also has the same 62% problem as Taguchi[4)].

Factor	R1（Ω）	R2（Ω）	R3（Ω）	R4（Ω）	Tr1	Tr2	N1	N2	SN	y
Optmum	18500	330	900	250	60	60	15.73	23.12	11.24	19.43

Table 13: Optimal Conditions for DSD.

C_6 and [a,b] analysis

Conduct [a,b] analysis using C_6+ in the upper row and C0 in the lower row of Table 11. Create factor effects (Figure 7) from the regression coefficients on the right side of Table 12, and mark their maximum values with a circle. Mark experimental maximum value No. 6 with the square marks.

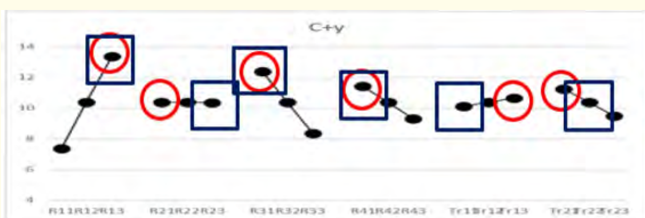

Figure 7: Factor Effects of C6+C0 and [a,b] Analysis.

Assuming that R_1, R_3, and R_4, for which the factor effects are large and the circles and squares match, are main effects, we set new levels for R_1 (18,500), R_3 (900, 600, 300), and R_4 (250, 200, 150) based on the square level (maximum response) in the direction of increasing response y. R_2, Tr1, and Tr2, for which the circles and squares do not match, are assumed to be affected by multifactorial interactions and are fixed at the same level as the previous level. This is shown in Table 14. The best square (No. 6) for the next experiment is set in the first row. Therefore, the rightmost and leftmost columns of Table 10 are swapped, as shown in Table 15. The experimental table and results are shown in Table 16.

Factor	R1（Ω）	R2（Ω）	R3（Ω）	R4（Ω）	Tr1	Tr2
−1	30000	330	300	250	60	60
0	2500	560	600	200	35	100
1	18500	950	900	1550	20	170

Table 14: Factors and levels for improving response.

Factor	R1（Ω）	R2（Ω）	R3（Ω）	R4（Ω）	Tr1	Tr2
1	1	1	1	-1	1	0
2	1	0	1	1	-1	1
3	-1	1	0	1	1	1
4	-1	1	1	0	-1	-1
5	-1	-1	1	-1	0	1
6	0	1	-1	-1	-1	1
13	0	0	0	0	0	0

Table 15: C_6 matrix with the first row being the previous No. 6.

Factor	R1（Ω）	R2（Ω）	R3（Ω）	R4（Ω）	Tr1	Tr2	N1	N2	y
1	18500	950	900	250	20	100	10.898	21.373	16.14
2	18500	560	900	1550	60	170	16.068	22.748	19.41
3	30000	950	600	1550	20	170	20.298	28.298	24.30
4	30000	950	900	200	60	60	17.042	23.652	20.35
5	30000	330	900	250	35	170	22.776	30.915	26.85
6	2500	950	300	250	60	170	27.747	35.029	31.39
13	2500	560	600	200	35	100	21.052	28.220	24.64

Table 16: C_6: Experimental table and results.

The response in the first row is 16.14, reproducing No. 6 in Table 12. Nos. 2 to 6 in Table 16 exceed No. 1 (16.14), [a, b] and the analysis results show a maximum response of 31.39, which is the optimal solution. Seven additional experiments were performed.

R_1, R_3, and R_4 correspond to columns 2, 3, and 4 of C_4 (Table 1), and R_2, Tr1, and Tr2 are fixed to the first row and shown in Table 17. Nos. 2 to 5 exceed No. 1, with a maximum value of 26.47, resulting in five additional experiments.

Factor	R1（Ω）	R2（Ω）	R3（Ω）	R4（Ω）	Tr1	Tr2	N1	N2	y
1	18500	950	900	250	20	100	10.90	21.37	16.14
2	25000	950	300	250	20	100	21.51	31.44	26.47
3	18500	950	600	150	20	100	14.16	23.14	18.65
4	30000	950	900	200	20	100	14.51	24.74	19.63
5	30000	950	600	200	20	100	16.13	25.88	21.01

Table 17: Applying R1, R3, and R4 to columns 2, 3, and 4 of C4 (Table 1).

Summary of overall experimental results

Table 18 summarizes the overall experimental results.

Style	Contents	Response type	Trials	Response
Stanard(2nd level)				10.64
Johns-DSD	C6+,C6-,C0	Max-Output	13	22.11
Johns-DSD	C6+,C6-,C0	Comb-Maineffect	14	19.43
[a,b]C6Analysis	C6+,C0,C6+,C0	Max-Output	14	31.39
[a,b]C4Analysis	C6+,C0,C4+,C0	Max-Output	12	26.47

Table 18: Summary of Overall Experimental Results.

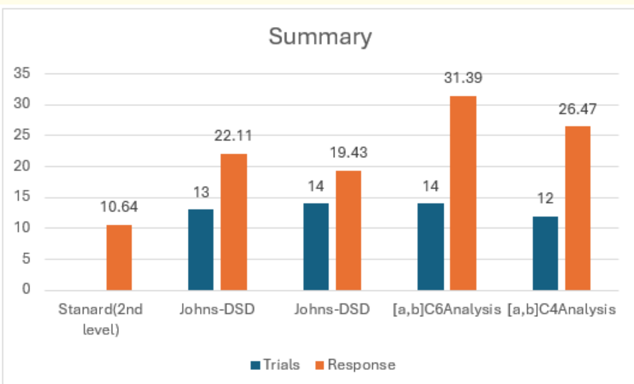

Figure 8: Overall results.

Overall summary using figure 8

The response, 10.36, on the left side of Figure 8 corresponds to the second level in Table 9. When the three-level, six-factor design in Table 9 is set to C_6+, C_6-, and C0 to form a DSD design, the maximum value is 21.11. Figure 6, obtained by regression analysis from this DSD response, shows the factor effect. This factor effect is free of confounding product and square terms. If the response were composed of linear terms and no higher-order terms, the response at the maximum level of the factor effect would coincide with the maximum value of all combinations. The predicted response should exceed the maximum value of 21.11 in Table 11. The measured response is 19.43 in Table 13, 1.68 lower than 21.11. Designers and researchers are disappointed by responses lower than the known maximum. This difference is due to the influence of higher-order terms within the response (here, between up to six factors).

On the other hand, Figure 7 shows the [a,b] analysis, which classifies whether the set level space is influenced by main effects and interactions based on design relationships. For factors R_1, R_3, and R_4, the □○ matches, so the main effect is established and the level is set on the upward side of the response, as shown in Table 14. Factors R_2, Tr1, and Tr2, where the □○ does not match, were set to the same level as Table 9. Table 16 shows the new C_6 allocation, but the levels are arranged in the same order as in Table 14 so that No. 1 is the same as □ (No. 6 in Table 11). No. 1 □ in Table 16 is 16.14, which is exceeded for all other Nos, with the maximum value being (No. 6) 31.39.

The above is C_6, but C_4 may also be used. R_1, R_3, and R_4 were assigned to columns 2, 3, and 4, and the multifactor level was fixed at No. 1. The results are shown in Table 17. No. 1 is 16.14, and the other four are higher, with the maximum being 26.47.

Conclusion

JONES (2011) proposed a three-level DSD by arranging the C matrix as [C+, C-, C0]. This matrix structure results in a DSD without any intermixing of first-order terms with second-order terms (product terms and squared terms). However, when applying [a,b] analysis to JONES (Table 6), it was determined that higher-order terms remained (Figure 1).

Then, verification was performed using a power supply circuit. The maximum response of the circuit DSD (Table 11) was 21.11, and the maximum confirmed value from its factorial effect was 19.43. Due to the influence of higher-order terms, this did not exceed the known maximum response of 21.11, disappointing designers (researchers).

On the other hand, [a,b] analysis of C6 increased the response from 16.14 to 31.39. Using C_4, the response increased from 16.14 to 26.47, both of which exceeded the known maximum values. [a,b] analysis, which can reliably achieve improved response characteristics, is suitable for design.

JONES: DSD is unsuitable due to a design defect that reduces response, but [a,b] analysis is suitable because it can improve response.

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Bibliography

1. Bradley Jones and Christopher J Nachtsheim. "A Class of Three-Level Designs for Definitive Screening in the Presence of Second-Order Effects". *Journal of Quality Technology* 43.1 (2011).
2. Part 2: C matrix and [a,b] analysis. Teruo Mori "Conference matrices for optimizing and applications". Spring Nature (2024): 95-171.
3. Kazuo Tatebayashi (2004): Nikka-Giren (Japan).