KOREA 2021

DISCOVERY SUMMIT

EXPLORING DATA
INSPIRING INNOVATION

jmp

최적화 방법의 새로운 접근

- Rubber Track 내구성 향상을 위한 Rubber Compound 개발 사례

Index

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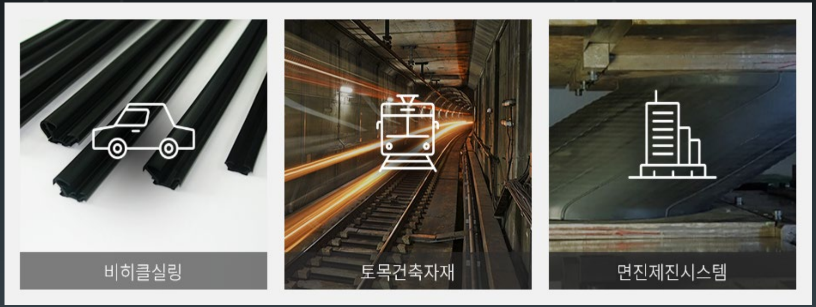
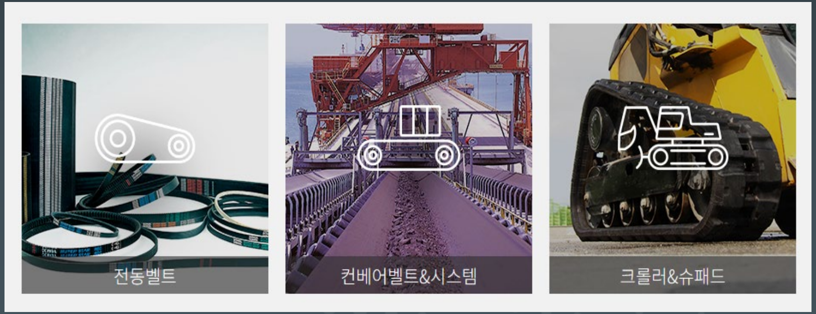
Introduction

- 주식회사 DRB동일



- 동일고무벨트 주식회사



Introduction

Global Network

국내공장 : 2
해외공장 : 5
해외판매법인 : 4
해외사무소 : 2

Introduction

CRS : 사용시간 25% 향상

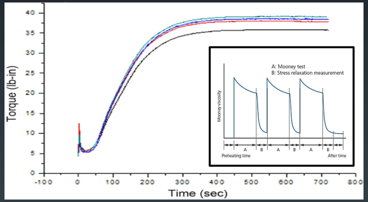
DRB

Rubber track Tread Process

Ingredients(x1~x6)

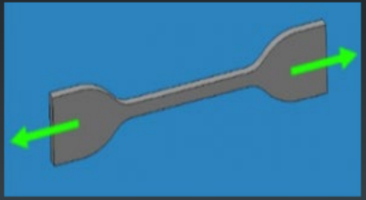
Weighing

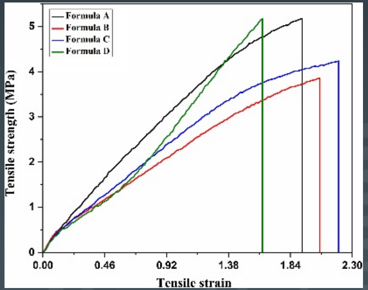
Output : y4~y7



Mixing

Output : y1,y2,y3





Physical property test

Final Out put : Durability

Using time(hrs)

jmp

DOE Concept

Factor	Level
X1	4
X2	3
X3	2
X4	2
X5	2
X6	2

Response
Y1
Y2
Y3
Y4
Y5
Y6
Y7

Full factorial Design → n = 192

Factor	Level
X1	4
X2	3
X3	Fixed
X4	
X5	
X6	

Full factorial Design
1st DOE → n = 12

Factor	Level
X1	Fixed
X2	
X3	2
X4	2
X5	2
X6	2

Full factorial Design
2nd DOE → n = 54

Factor	Level
X1	4
X2	3
X3	2
X4	2
X5	2
X6	2

Custom Design
3rd DOE → n = 48

1st DOE Design

Factor

	X1	X2
1	60:40	H60
2	70:30	I60
3	30:70	S60
4	40:60	

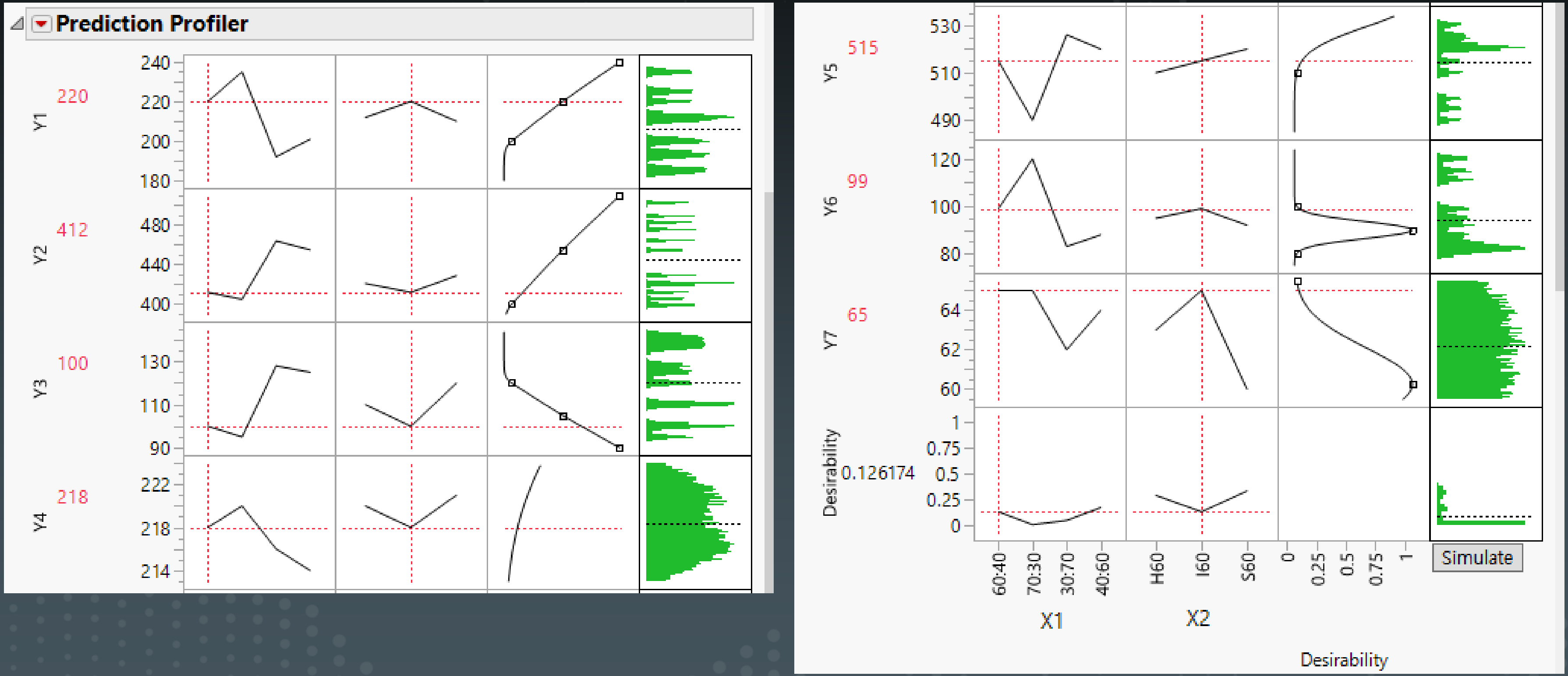
Response

	Response Name	Lower Limit	Upper Limit	Response Goal	Importance
1	Y1	200	•	Maximize	3
2	Y2	400	•	Maximize	3
3	Y3	•	120	Minimize	5
4	Y4	210	270	Match Target	1
5	Y5	510	570	Match Target	1
6	Y6	80	100	Match Target	10
7	Y7	55	•	Match Target	0.5

Design

Run	X1	X2
1	30:70	I60
2	60:40	S60
3	70:30	S60
4	70:30	H60
5	40:60	S60
6	30:70	H60
7	60:40	I60
8	40:60	I60
9	30:70	S60
10	60:40	H60
11	40:60	H60
12	70:30	I60

1st DOE Results



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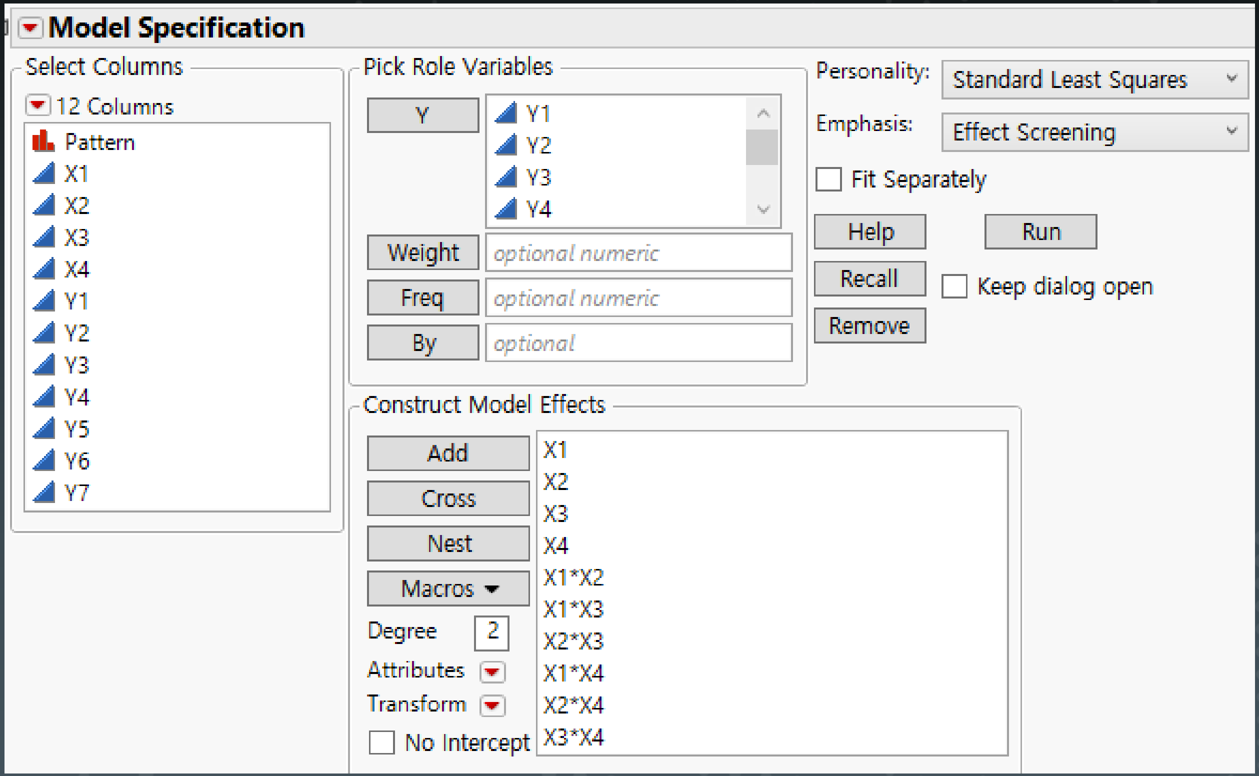
2nd DOE Design



2nd DOE Design

DRB

Screening Design

Responses

Add Response | Remove | Number of Responses...

Response Name	Goal	Lower Limit	Upper Limit	Importance
Y1	Maximize	200	.	3
Y2	Maximize	400	.	3
Y3	Minimize	.	120	5
Y4	Match Target	210	270	3
Y5	Match Target	510	570	1
Y6	Match Target	80	100	5
Y7(ML)	Match Target	55	65	1

Factors

Continuous | Discrete Numeric | Categorical | Remove | Add N Factors 1

Name	Role	Values	
X1	Continuous	1	3
X2	Continuous	0.2	0.5
X3	Continuous	0.2	2
X4	Continuous	0.2	2

Design

Run	X1	X2	X3	X4
1	3	0.2	2	2
2	2	0.35	1.1	1.1
3	1	0.5	0.2	0.2
4	3	0.2	2	0.2
5	2	0.35	1.1	1.1
6	1	0.5	0.2	2
7	3	0.5	0.2	0.2
8	3	0.2	2	0.2
9	3	0.5	2	2
10	3	0.5	0.2	0.2
11	1	0.2	0.2	2
12	1	0.2	0.2	2
13	1	0.5	2	2
47	1	0.2	2	2
48	1	0.5	2	2
49	2	0.35	1.1	1.1
50	1	0.5	0.2	2
51	1	0.5	0.2	2
52	3	0.2	2	2
53	1	0.5	2	0.2
54	3	0.5	0.2	2

2nd DOE Result

Least Squares Fit

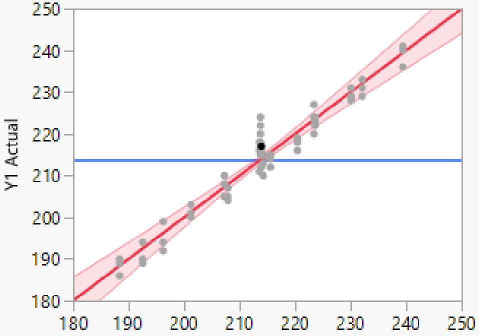
Effect Summary

Source	LogWorth	PValue
X1(1,3)	25.749	0.00000
X2(0.2,0.5)	24.184	0.00000
X3(0.2,2)	21.076	0.00000
X4(0.2,2)	15.624	0.00000
X2*X3	11.712	0.00000
X2*X4	4.678	0.00002
X3*X4	4.414	0.00004
X1*X2	2.678	0.00210
X1*X3	1.898	0.01265
X1*X4	0.668	0.21476

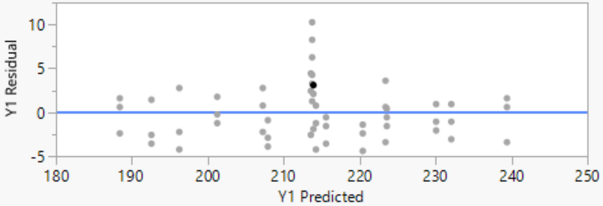
Remove Add Edit FDR

Response Y1

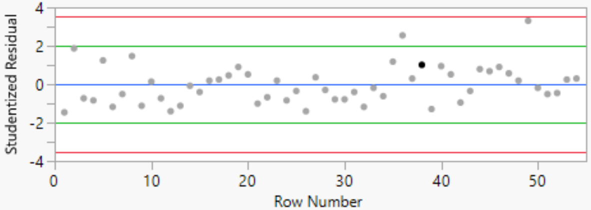
Actual by Predicted Plot



Residual by Predicted Plot



Studentized Residuals



Externally studentized residuals with 95% simultaneous limits (Bonferroni) in red, individual limits in green.

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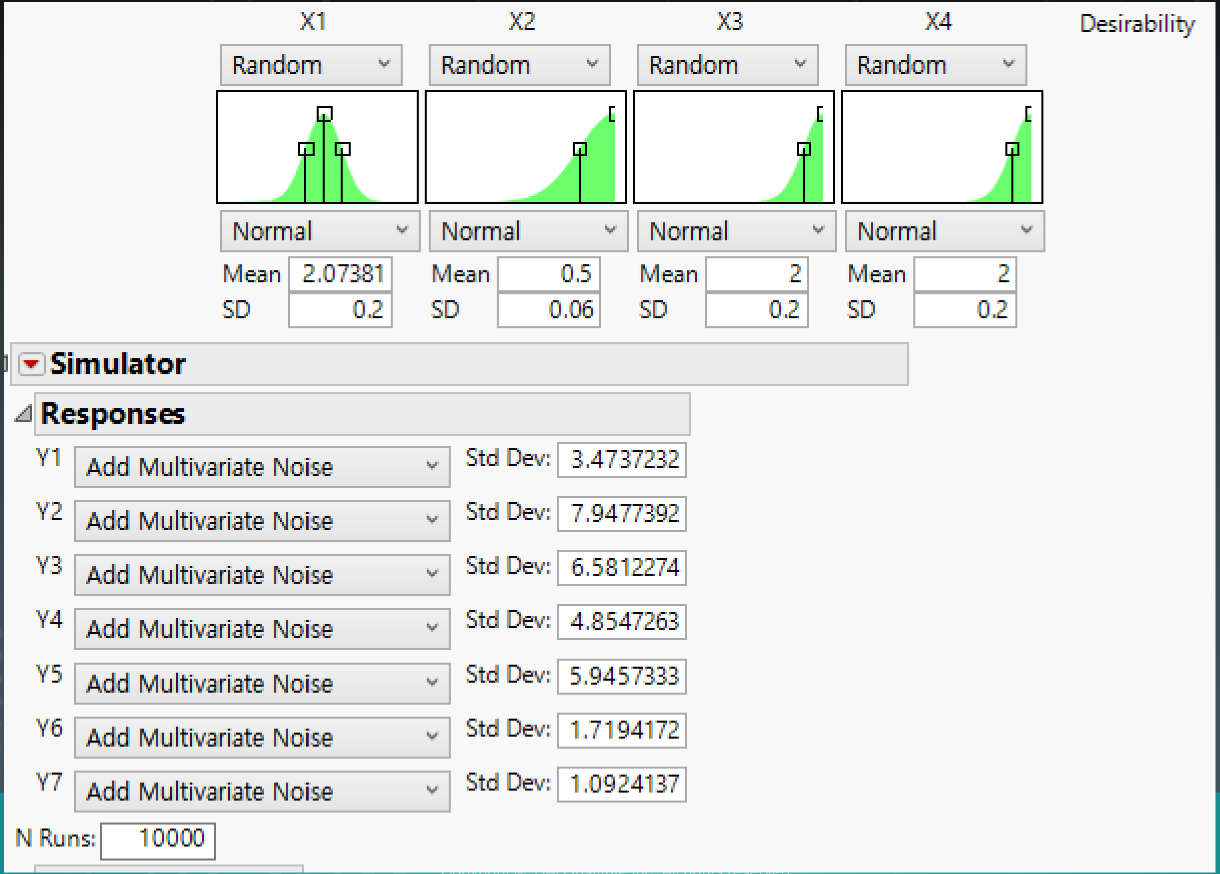
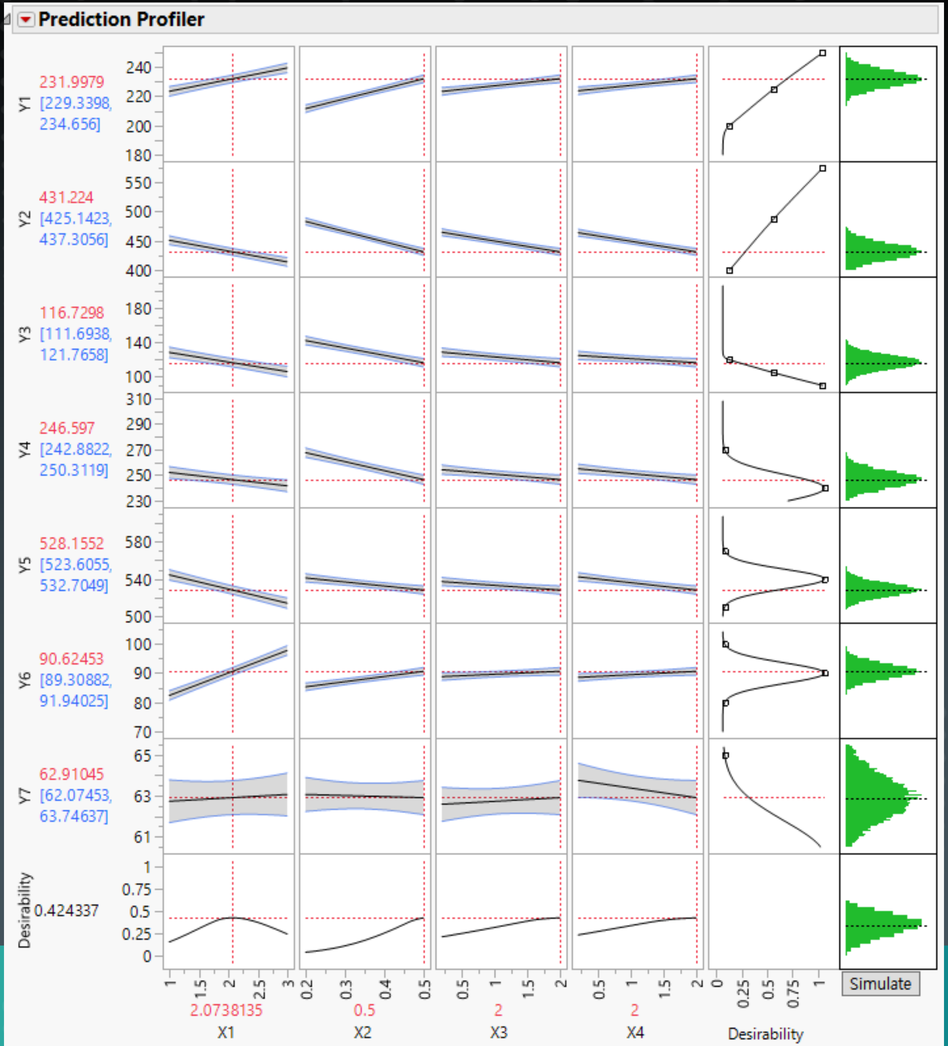
2nd DOE Result



2nd DOE Result



Summary of 1st, 2nd DOE

DRB

Factor	Level
X1	4
X2	3
X3	Fixed
X4	
X5	
X6	

Factor	Level
X1	Fixed
X2	
X3	2
X4	2
X5	2
X6	2

Factor	Level
X1	60:40
X2	I60
X3	2.07
X4	0.5
X5	2
X6	2

Response	
Y1	231
Y2	431
Y3	116
Y4	246
Y5	528
Y6	91
Y7	63

3rd DOE by Custom Design

Factor

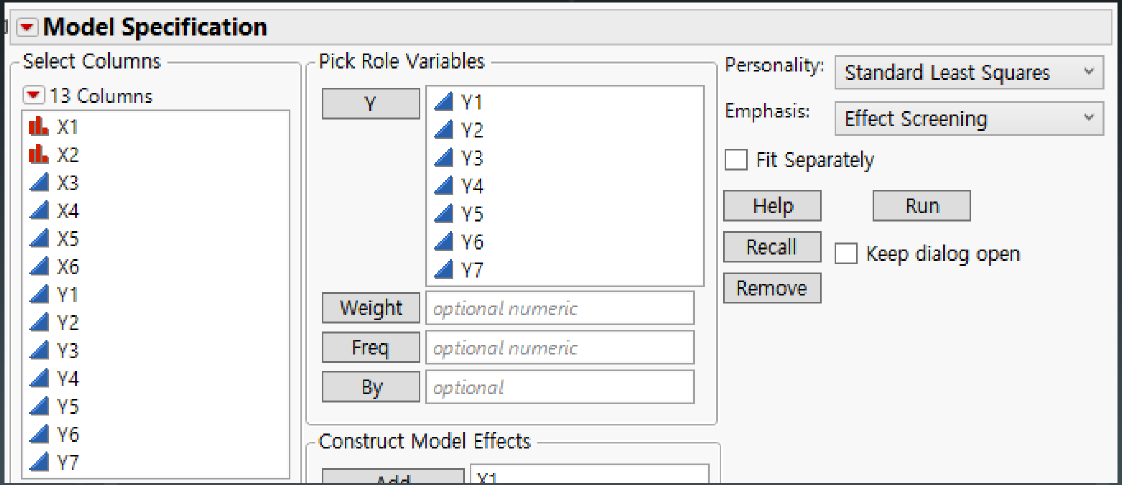
	X1	X2	X3	X4	X5	X6
1	70:30	H60	1	0.2	0.2	0.2
2	60:40	I60	3	0.5	2	2
3	40:60	S60	•	•	•	•
4	30:70		•	•	•	•

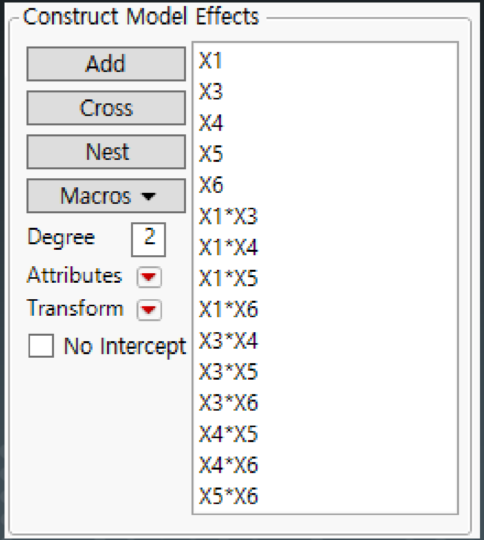
Response

	Response Name	Lower Limit	Upper Limit	Response Goal	Importance
1	Y1	200	•	Maximize	3
2	Y2	400	•	Maximize	3
3	Y3	•	120	Minimize	5
4	Y4	210	270	Match Target	3
5	Y5	510	570	Match Target	1
6	Y6	80	100	Match Target	5
7	Y7	55	65	Match Target	1

	X1	X2	X3	X4	X5	X6
1	30:70	H60	3	0.2	0.2	2
2	70:30	H60	1	0.5	2	0.2
3	70:30	I60	1	0.5	0.2	0.2
4	30:70	H60	1	0.5	2	2
5	40:60	S60	1	0.5	0.2	0.2
6	40:60	S60	3	0.2	0.2	0.2
7	60:40	H60	3	0.2	0.2	0.2
38	40:60	I60	3	0.5	0.2	2
39	70:30	I60	3	0.5	2	2
40	30:70	I60	3	0.2	2	2
41	30:70	I60	1	0.5	0.2	2
42	70:30	H60	1	0.2	0.2	0.2
43	30:70	S60	3	0.2	2	0.2
44	60:40	S60	3	0.5	2	0.2
45	60:40	S60	3	0.2	0.2	2
46	30:70	S60	3	0.5	0.2	2
47	40:60	H60	1	0.2	2	0.2
48	70:30	I60	3	0.2	0.2	2

3rd DOE by Custom Design





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DRB

3rd Custom Design Result

Least Squares Fit

Effect Summary

Source	LogWorth	PValue	
X3(1,3)	6.388	0.00000	
X3*X4	4.910	0.00001	
X4(0.2,0.5)	4.709	0.00002	^
X1	3.744	0.00018	
X1*X4	3.259	0.00055	
X6(0.2,2)	3.048	0.00089	
X1*X3	2.580	0.00263	
X2	2.188	0.00649	
X1*X2	2.024	0.00946	
X2*X6	1.586	0.02594	
X5*X6	1.545	0.02852	
X2*X4	1.532	0.02935	
X3*X5	1.190	0.06454	
X2*X3	1.138	0.07273	
X4*X6	0.978	0.10521	
X1*X5	0.848	0.14184	
X2*X5	0.791	0.16194	
X4*X5	0.738	0.18285	
X3*X6	0.726	0.18781	
X5(0.2,2)	0.716	0.19225	^
X1*X6	0.506	0.31186	

Remove Add Edit ☐ FDR ('^' denotes effects with containing effects above them)

Least Squares Fit

Effect Summary

Source	LogWorth	PValue	
X3(1,3)	11.635	0.00000	
X3*X4	8.637	0.00000	
X4(0.2,0.5)	8.358	0.00000	^
X1*X4	5.894	0.00000	
X1	5.852	0.00000	^
X6(0.2,2)	4.462	0.00003	
X1*X3	4.304	0.00005	
X1*X2	3.892	0.00013	
X2	2.759	0.00174	^
X2*X6	2.609	0.00246	
X2*X4	1.811	0.01544	
X2*X3	1.722	0.01896	
X5*X6	1.712	0.01943	
X3*X5	1.598	0.02524	
X1*X5	1.535	0.02920	
X5(0.2,2)	1.290	0.05126	^

Remove Add Edit Undo ☐ FDR ('^' denotes effects with containing effects above them)

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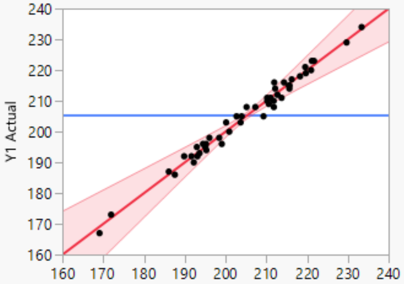
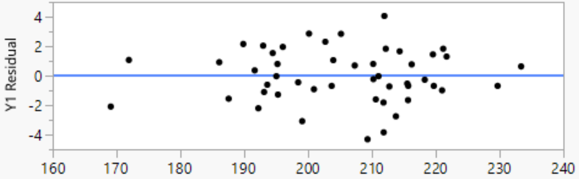
3rd Custom Design Result

Response Y1

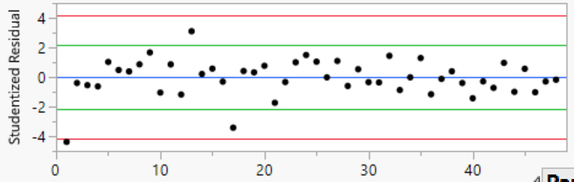
Actual by Predicted Plot



Residual by Predicted Plot



Studentized Residuals



Externally studentized residuals with 95% simultaneous limits (Bonferroni) in red, in green.

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	205.27083	0.474127	432.94	<.0001*
X3(1,3)	7.3708333	0.492727	14.96	<.0001*
X4(0.2,0.5)	6.8369069	0.537201	12.73	<.0001*
X1[40:60]*X3	-5.526369	0.896633	-6.16	<.0001*
X1[40:60]*X2[I60]	-5.932906	1.302152	-4.56	0.0004*
X1[40:60]*X4	4.364188	1.004907	4.34	0.0007*
X2[I60]	2.9416667	0.70004	4.20	0.0009*
X1[60:40]*X2[I60]	4.952255	1.269941	3.90	0.0016*
X3*X4	-1.931548	0.498881	-3.87	0.0017*
X1[70:30]	3.060371	0.856423	3.57	0.0031*
X6(0.2,2)	1.8799603	0.533445	3.52	0.0034*
X1[70:30]*X2[I60]	4.4144117	1.269941	3.48	0.0037*
X1[70:30]*X5	-3.054897	0.928197	-3.29	0.0054*
X2[H60]*X6	-2.341704	0.819566	-2.86	0.0127*
X2[I60]*X3	-1.908333	0.673861	-2.83	0.0133*
X1[60:40]*X3	2.3940476	0.860549	2.78	0.0147*
X3*X5	1.1875	0.474127	2.50	0.0252*
X5(0.2,2)	1.0416667	0.488719	2.13	0.0513

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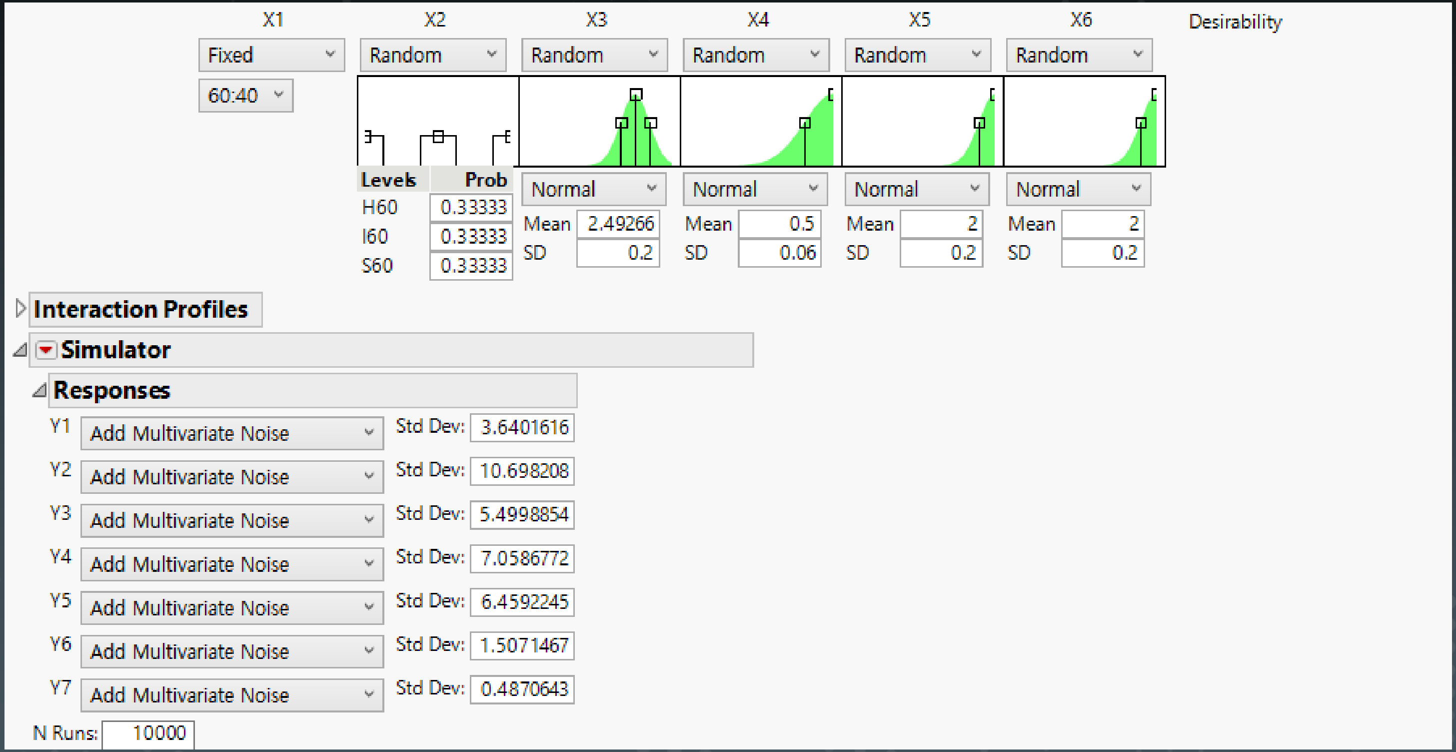
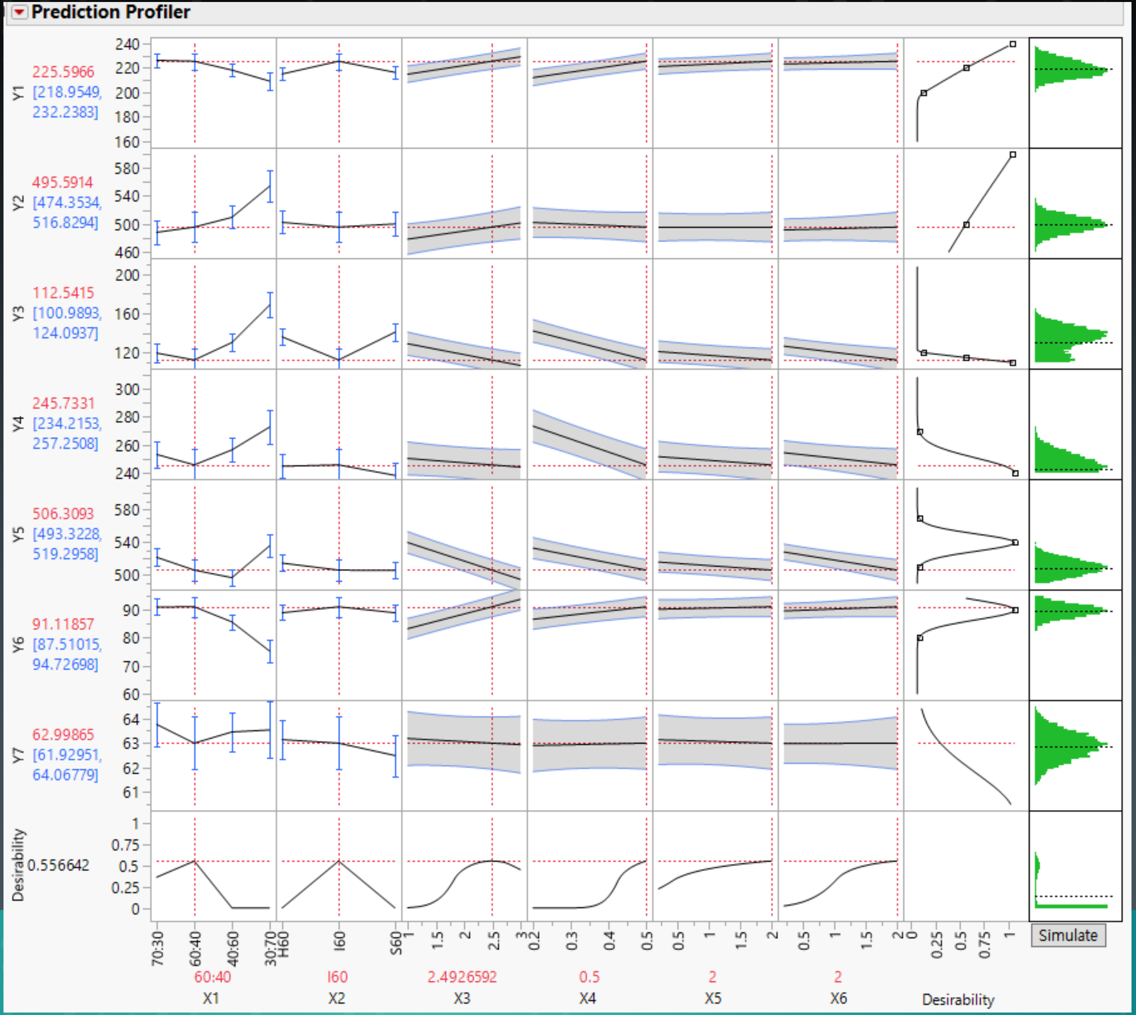
3rd Custom Design Result

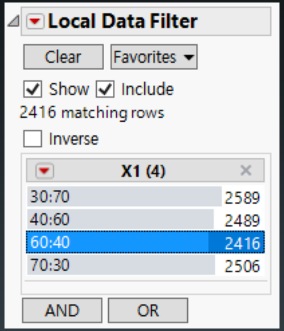


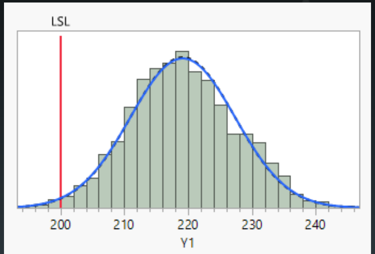
3rd Custom

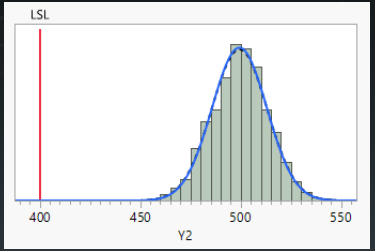


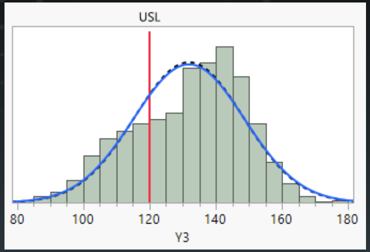
Prediction Profiler
Y1
225.5966
[218.9549,
232.2383]
Y2
495.5914
[474.3534,
516.8294]
Y3
112.5415
[100.9893,
124.0937]
Y4
245.7331
[234.2153,
257.2508]
Y5
506.3093
[493.3228,
519.2958]
Y6
91.11857
[87.51015,
94.72698]
Y7
62.99865
[61.92951,
64.06779]
Desirability
0.556642
60:40
X1
I60
X2
2.4926592
X3
0.5
X4
2
X5
2
X6
Desirability
Simulate

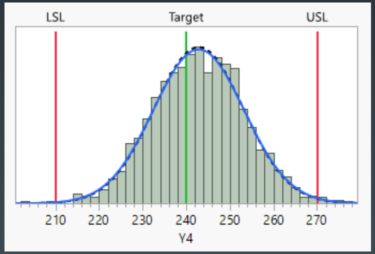
3rd Custom Design Result

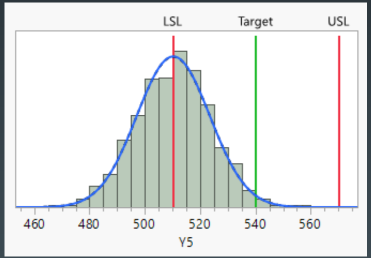


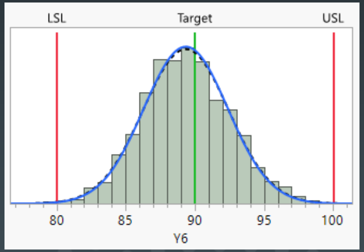


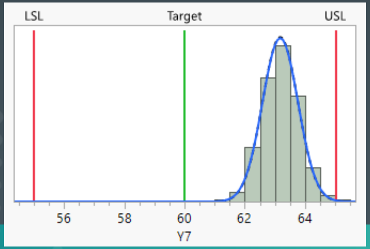




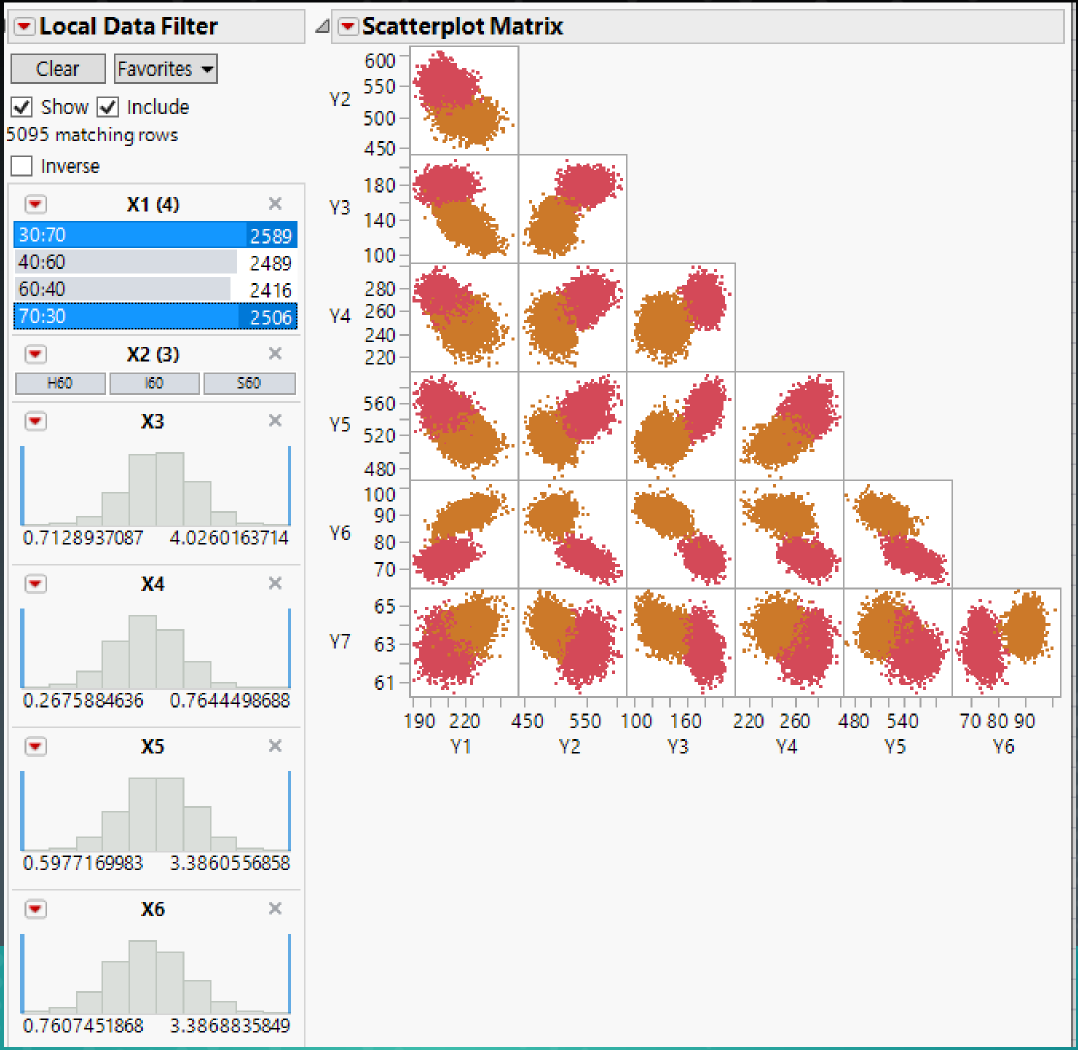






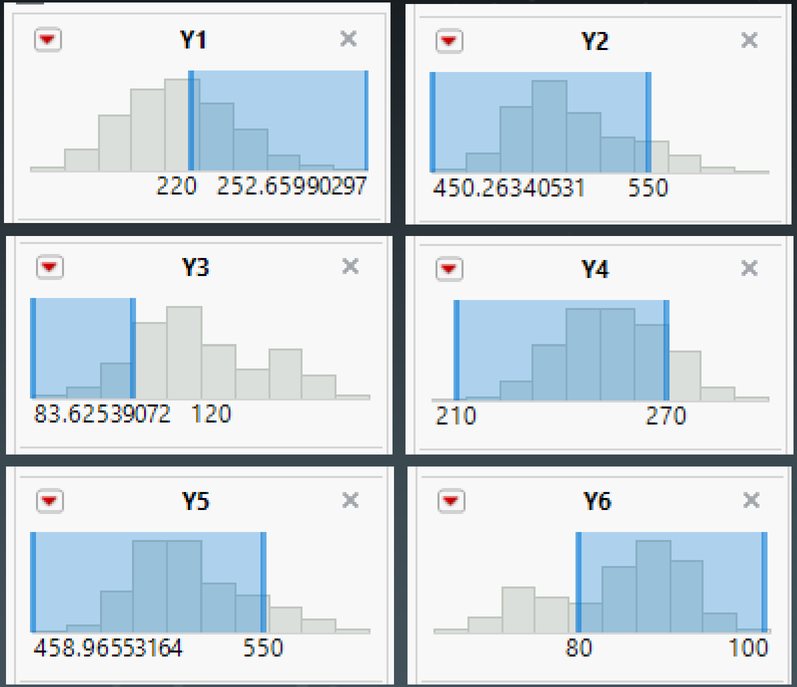


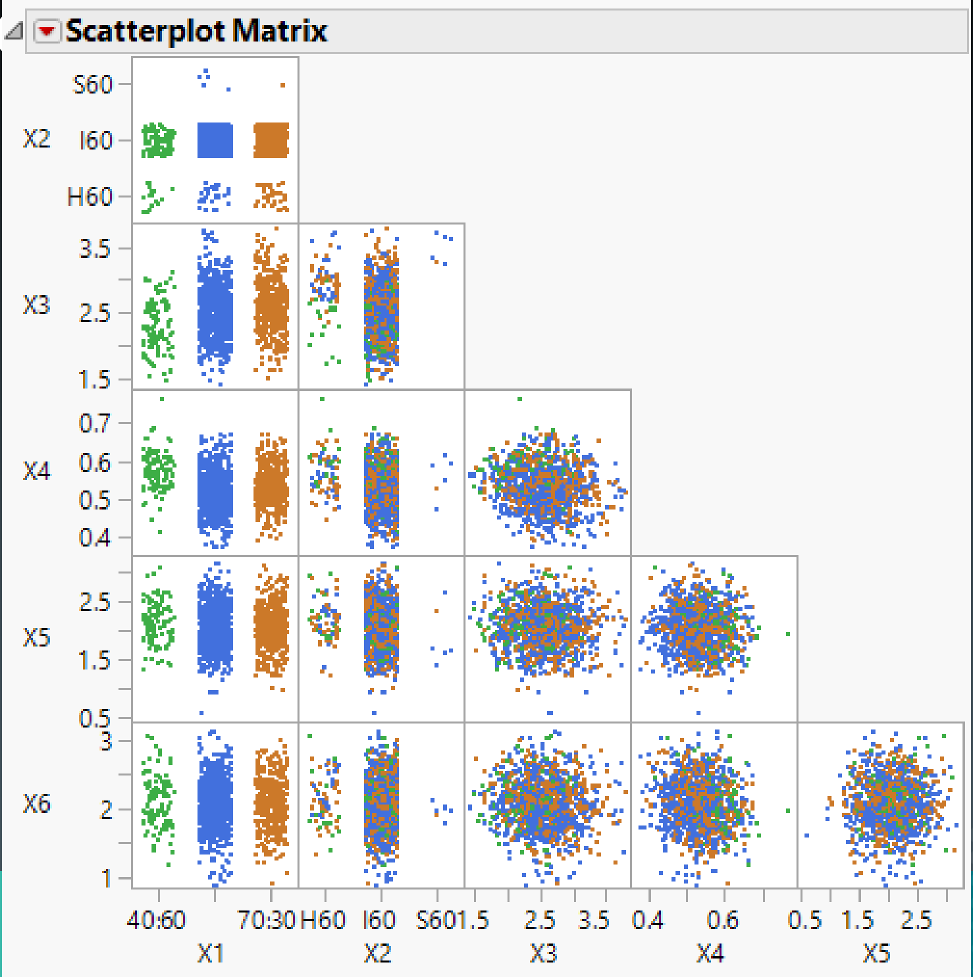
3rd Custom



Local Data Filter
Clear
Favorites
Show
Include
5095 matching rows
Inverse
X1 (4)
30:70 2589
40:60 2489
60:40 2416
70:30 2506
X2 (3)
H60
I60
S60
X3
0.7128937087 4.0260163714
X4
0.2675884636 0.7644498688
X5
0.5977169983 3.3860556858
X6
0.7607451868 3.3868835849
Scatterplot Matrix
Y2
Y3
Y4
Y5
Y6
Y7
Y1

3rd Custom Design Re





Conclusion

- 이전의 통계프로그램으로도 배합개발의 목적을 달성할 수 있었습니다. 하지만 JMP의 Custom Design을 통해 더 적은 실험횟수로도 같은 목적을 달성할 수 있었음
- 적은 횟수의 실험결과로 모델링하였을 때, 이전에 발견하지 못한 다양한 조건에서도 배합개발 목적을 달성할 수 있는 방법이 있음을 확인할 수 있었음
- JMP의 Custom Design을 통해 적은 시간과 비용의 결과로 Simulation / Distribution 기능을 통해 대량 생산시 불량율을 예측 할 수 있었음

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