COST-EFFECTIVE AND INFORMATION-EFFICIENT ROBUST DESIGN FOR OPTIMIZING PROCESSES AND ACCOMPLISHING SIX SIGMA OBJECTIVES

POSTSCRIPT

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Table 3 shows the results from a hypothetical connector experiment done via the two-array Taguchi parameter design.

				Outer Array (noise variables)									
			Std →	1	2	3	4	5	6	7	8		
			D	–	+	–	+	–	+	–	+		
			E	–	–	+	+	–	–	+	+		
			F	–	–	–	–	+	+	+	+		
			G	–	+	+	–	+	–	–	+		
Inner Array (control factors)				**Raw Data**								**Responses**	
Std	A	B	C									Mean	Std. Dev.
1	–	–	–	17.54	**23.09**	12.47	**14.75**	**15.61**	21.23	**13.82**	14.96	16.68	3.71
2	+	–	–	**14.56**	22.15	**10.39**	11.04	22.73	**27.64**	18.69	**18.75**	18.24	5.99
3	–	+	–	**14.52**	21.00	**14.38**	17.27	13.26	**18.85**	14.98	**15.66**	16.24	2.61
4	+	+	–	12.04	**16.60**	12.69	**14.12**	**16.62**	22.52	**19.41**	20.06	16.76	3.72
5	–	–	+	**20.96**	28.74	**19.57**	19.23	21.09	**27.69**	17.15	**20.02**	21.81	4.15
6	+	–	+	19.22	**26.69**	16.99	**17.68**	**26.29**	33.00	**24.39**	24.16	23.55	5.40
7	–	+	+	19.32	**22.52**	21.55	**21.21**	**17.01**	22.54	**19.99**	21.93	20.76	1.90
8	+	+	+	**15.43**	22.06	**17.57**	19.88	22.82	**26.66**	24.08	**26.97**	21.93	4.12

Table 3: Parameter design for connector study

Embedded (shown in bold) within the 64 responses are the 32 results for pull-off force from the one-array design (2^{7-2} standard quarter-fraction) listed in Table 2. The new results (32 numbers not in bold) came from the same simulation used for the previous experiment. Let's see what the statistical analysis reveals and whether, given twice the amount of data as a one-array standard fraction, a two-array parameter design accomplishes the objectives of robust design. We begin by viewing the half-normal plot of the effects (Figure 10).

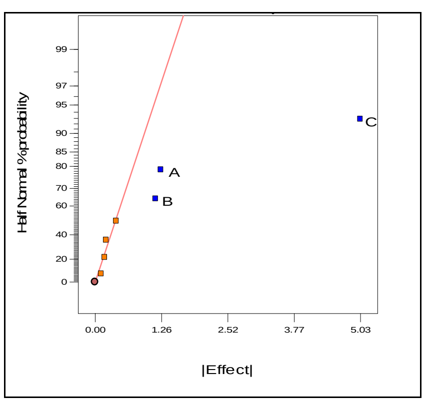
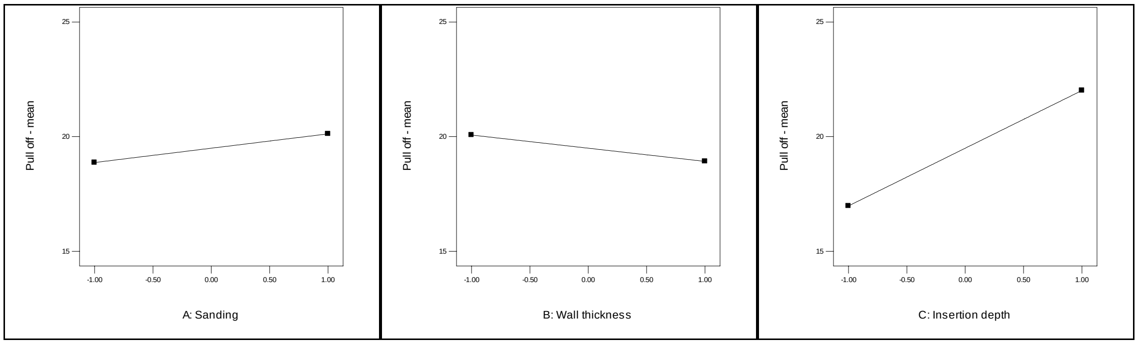


Figure 10: Mean effects plot – parameter design

The labeled effects (A, B and C) are statistically significant with more than 95% confidence according to analysis of variance (ANOVA). Figures 11a,b and c show response plots of these three main effects.



Figures 11a, b &c: Effects of A, B and C (left-to-right) on mean response

Before deciding which levels to choose for the three process factors, let's look at the half-normal plot of effects on standard deviation (Figure 12) in $\log_{10}$ scale (a standard transformation for variability as a response).

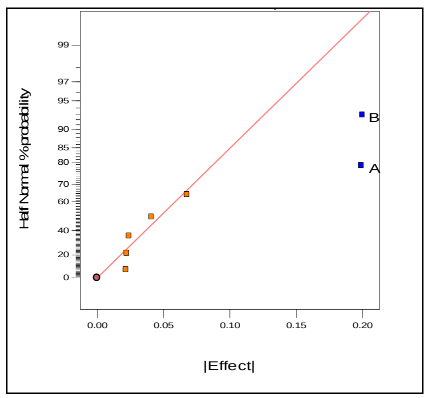
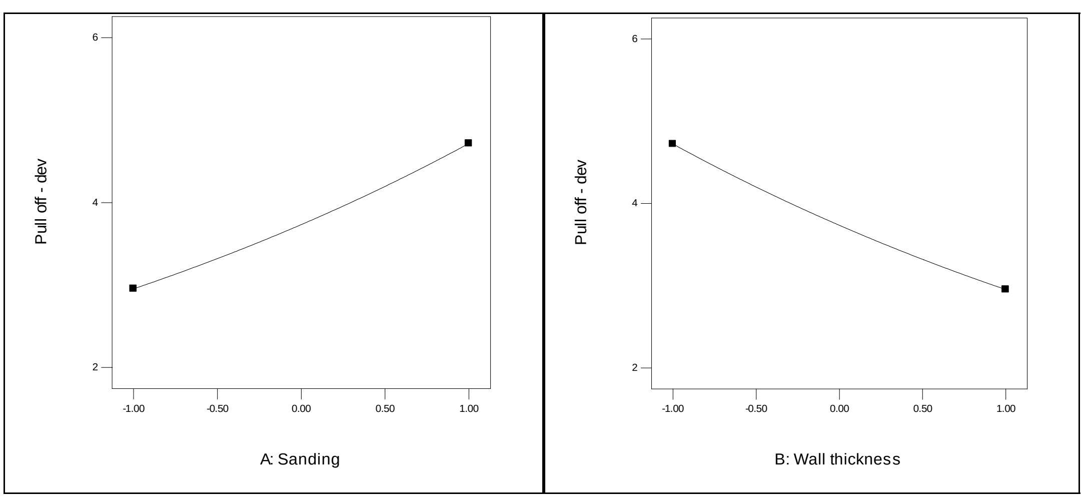


Figure 12: Standard deviation effects plot – parameter design

The labeled effects (A and B) are statistically significant with more than 99% confidence according to analysis of variance (ANOVA). Figures 13a and b show response plots of these two main effects.



Figures 13a, b: Effect of A and B (left-to-right) on standard deviation of response

Now it can be seen that to minimize variation in the process, factor A (sanding) must be set low and factor B (wall thickness) must be at its highest level. This same conclusion was reached with the one-array design alternative containing only half the runs of this two-array Taguchi design. As we previously discussed, setting A and B to minimize variation make these two factors inflexible for controlling the response. That's where factor C (insertion depth) once again comes into play. As illustrated in Figure 11c, it creates a big effect on the mean response, but nothing significant on the standard deviation. Therefore, by using this figure as an operating curve, the experimenter can adjust factor C upwards or downwards to increase or decrease the response (pull-off force) so it meets the required specification (not shown, but presumably a range – not too low or too high).

Unfortunately, by separating out the control factors from the noise variables, the Taguchi design – despite having twice the number of runs – does not reveal the DE interaction (time-temperature) effect, which we know is present from the one-array results. This is an opportunity lost – knowing that temperature (E) could be controlled in the warehouse, thus making the process more robust to variations in storage time (D).

This postscript provides detailed support for our previous conclusion: The two-array parameter design generates the same results in terms of where to set factors A, B and C, but with twice the effort (64 runs) of the 32-runs in the single-array design (2^{7-2}), and it fails to reveal valuable information on interactions of noise variables.