Valve Design Optimization

Asaki Valve Works (AVW) designs and mass produces valves for specialty engines. For a particular engine block and valve cover design, valves can be manufactured conforming to three design parameters: seating angle (θ), clearance (d) and tension (t). While the parameter values can have narrow ranges, the particular values can have a significant effect on their performance. The company would like to determine design parameter values that maximize performance efficiency.

The efficiency $E(\theta, d, t)$ is a nonlinear function of the design parameters. This function is not known explicitly. Furthermore, numerical simulations are known to predict efficiency with high uncertainty and low accuracy. So, the company experimentally measures efficiency in their testing lab, but it takes several days to manufacture a valve for testing.

For a particular customer, the company initially produced eight valves of differing parameter values suggested by company engineers. These valves were tested with the following results.

Valve # (k):	1	2	3	4	5	6	7	8
Efficiency E_k :	0.009	0.132	0.018	0.249	0.034	0.049	0.110	0.027
Seating Angle θ_k [°]	4.8	3.5	4.8	3.0	4.2	2.2	4.2	2.6
Clearance d_k [mm]	1.0	1.8	2.8	1.9	1.4	1.6	2.1	2.8
Tension t_k [10^2N]	2.6	1.9	1.1	3.1	3.3	1.2	2.9	1.8

Previous results on other engine designs suggest that efficiencies above 0.85 are typically achievable. The company would like to solve the optimization problem

$$\begin{aligned} \max_{\theta,d,t} \quad & E(\theta, d, t) \\ \text{s.t} \quad & 0 \le \theta \le 5 \\ & 1 \le d \le 3 \\ & 1 \le t \le 4 \end{aligned}$$

The only way to evaluate $E(\theta, d, t)$ is to manufacture and test a valve. So, the company would like to have a strategy for deciding likely designs of high efficiency. The company has the ability to manufacture and test up to two different designs nearly simultaneously.

The company has recently retained a class of optimization students to explore this problem. Your task is to determine a high efficiency valve design by the end of the semester. Each request to the manufacturing and testing facility takes one week and can consist of up to two distinct designs. Each Wednesday, the team will choose two designs to test. I will provide the testing results within about one day – just to give you enough time to collaborate before the next Wednesday. Wouldn't it be interesting if I used your best efficiency as your course grade?