
Design of Experiments Example: A Design with Fixed Covariates

In this example, you are interested in modeling the Shrinkage of parts produced by an injection molding process. The Thermoplastic.jmp sample data table in the Design Experiment folder lists 25 batches of raw (thermoplastic) material for potential use in your study. For each batch, material was removed to obtain measurements of Specific Gravity and Tensile Strength. A third covariate, Supplier, is also available.

You want to study the effects of three controllable factors, Temperature (mold temperature), Speed (screw speed), and Time (hold time), on Shrinkage. But you also want to study the effects of the covariates: Specific Gravity, Tensile Strength, and Supplier. Your resources allow for 12 runs.

Create the Design

1. Select **Help > Sample Data Library** and open Design Experiment/Thermoplastic.jmp.
2. Select **DOE > Custom Design**.
3. Double-click Y under Response Name and type Shrinkage.
4. Click **Maximize** under Goal and change it to **Minimize**.
5. Click **Add Factor** and select **Covariate**.
6. Select Specific Gravity, Tensile Strength, and Supplier from the list and click **OK**.
These are covariates and cannot be controlled.
7. Type 3 next to **Add N Factors**.
8. Click **Add Factor > Continuous**.
9. Rename the three continuous factors Temperature, Speed, and Time.
These are factors that can be controlled.

Figure 1 Responses and Factors Outlines

Responses

Add Response ▼ Remove Number of Responses...

Response Name	Goal	Lower Limit	Upper Limit	Importance
Shrinkage <i>optional item</i>	Minimize	.	.	.

Factors

Add Factor ▼ Remove Add N Factors 1

Name	Role	Changes	Values
▲ Specific Gravity	Covariate	Easy	1.004 1.144
▲ Tensile Strength	Covariate	Easy	6.42 8.07
▼ Supplier	Covariate	Easy	A B C
▲ Temperature	Continuous	Easy	-1 1
▲ Speed	Continuous	Easy	-1 1
▲ Time	Continuous	Easy	-1 1

Specify Factors
Add a factor by clicking the Add Factor button. Double click on a factor name or level to edit it.

Continue

10. Click **Continue**.

The Number of Runs shows the number of rows with covariate values available. You have 25 batches with measured covariates.

11. Type 12 next to **Number of Runs**.

Note: Setting the Random Seed in step 12 and Number of Starts in step 13 reproduces the exact results shown in this example. In constructing a design on your own, these steps are not necessary.

12. (Optional) From the Custom Design red triangle menu, select **Set Random Seed**, type 84951, and click **OK**.13. (Optional) From the Custom Design red triangle menu, select **Number of Starts**, type 40, and click **OK**.14. Click **Make Design**.

Figure 2 Twelve-Run Optimal Design

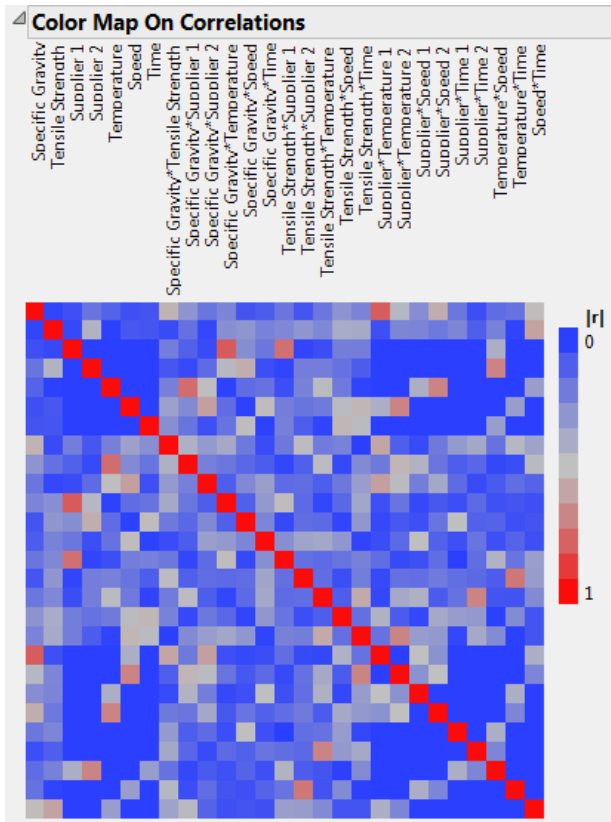
Design							
Run	Specific Gravity	Tensile Strength	Supplier	Temperature	Speed	Time	
1	1.107	8.07	B	1	1	1	1
2	1.144	6.82	B	1	-1	-1	-1
3	1.004	6.52	C	1	1	-1	-1
4	1.015	7.46	A	-1	1	-1	-1
5	1.129	6.97	A	1	-1	-1	-1
6	1.139	6.94	C	-1	1	-1	-1
7	1.004	7.12	C	1	-1	1	1
8	1.067	6.7	B	-1	1	1	1
9	1.047	6.42	A	-1	-1	1	1
10	1.03	7.54	B	-1	-1	-1	-1
11	1.094	6.48	A	1	1	1	1
12	1.113	6.89	C	-1	-1	1	1

This design is D-optimal, given the potential covariate values. It selects the best sets of covariate values and the best settings for the three controllable factors.

Evaluate the Design

1. Open the **Design Evaluation > Color Map On Correlations** outline.

Figure 3 Color Map on Correlations



The seven terms corresponding to main effects appear in the upper left corner of the color map. Notice that these seven terms are close to orthogonal. The largest absolute correlation is between Tensile Strength and Supplier 2. This absolute correlation of about 0.43 is a consequence of the available covariate values. (Figure 3 uses JMP default colors.)