# Example 6 - DoE data (Pressure Die Casting)

This example shows the effective use of the p-matrix Data Visualizer 2013 software to analyse Design of Experiment data in a pressure die casting environment.

**The Problem:** A pressure die casting facility is having a problem with Porosity in one of its parts which is being produced on a machine with two die cavities. The process experts identified four parameters which they wanted to investigate more. An experiment was setup to investigate the effect of each of the parameters on the occurrence of Porosity.

Each parameter had three levels as shown in the Table below which were set at to investigate new and existing settings for the process. Eight experiments were carried out, with five castings being produced from each cavity. A score was given based on size and location of the porosity. The table below shows the average Porosity Score for each experiment.

| Process Settings | | | | |
|---|---|---|---|---|
| | Fast Shot Velocity | Cavity Prefill | Intermediate Velocity | Spray Time |
| Batch1 | 90 | 6 | 16 | 1.7 |
| Batch2 | 90 | 22 | 20 | 2.6 |
| Batch3 | 90 | 40 | 25 | 3.3 |
| Batch4 | 105 | 6 | 20 | 3.3 |
| Batch5 | 105 | 40 | 16 | 2.6 |
| Batch6 | 120 | 6 | 25 | 2.6 |
| Batch7 | 120 | 22 | 16 | 3.3 |
| Batch8 | 120 | 40 | 20 | 1.7 |

| Porosity Score | |
|---|---|
| Cavity1 | Cavity2 |
| 6 | 6 |
| 6 | 6 |
| 6 | 5 |
| 4 | 6 |
| 4 | 2 |
| 4 | 4 |
| 5 | 2 |
| 5 | 1 |

**The Solution:** More insight into process behaviour is achieved by using p-matrix's quartile analysis for continuous parameters that accurately distinguish the effects of subtle changes to the process. It groups settings into top, middle and bottom ranges to check if a parameter setting can explain the deviation from desired response values. p-matrix is based on pattern recognition and therefore is more reliable in discovering correlations as compared to the statistical techniques.

**Penalty Function for Porosity Score in both cavities:** The software penalizes the deviation in desired response values depending upon severity. It applies 0 penalty value to desired Porosity Score values, 100 penalty values to undesired Porosity Score values and linearly scales the remaining values from 1 to 99.

| Response Name | Penalty function | Desired values | Undesired values |
|---|---|---|---|
| Porosity Score: Cavity1 | Lower the better | Below 4.5 | Above 5.5 |
| Porosity Score: Cavity2 | Lower the better | Below 3.5 | Above 4.5 |

**p-matrix Report:** p-matrix software characterises process settings as optimal and avoid depending on whether they cause good and bad results for the Porosity Scores for both cavities. The process engineer was able to evaluate all the ranges given in the various sheets of p-matrix report to recommend a confirmation trial plan for the 7Epsilon Quality Control meeting.

**Confirmation Trial Plan:** The report shows that 'Fast Shot Velocity' in its Bottom 50% range i.e. {>=90 & <=105}, can produce a part with a severe Porosity defect. Strong evidence in the data suggests that setting 'Fast Shot Velocity' to its Top 50% range i.e. [>105 & <=120], will significantly increase the chances of casting part with little or no porosity in both cavities: Cavity1 and Cavity2, as shown in the Figures below.

**Fast Shot Velocity for Cavity1**

| Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|
| Minimum | | Median | | Maximum |
| 90 | 90 | 105 | 120 | 120 |

Q1: Avoid; Range: Bottom 25%, {>=90 & <=90}; Strength: 3.6;

| Penalty | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|
| 80-100 | 12 | 1 | | 1 |
| 60-80 | | | | |
| 40-60 | 2 | 2 | | 6 |
| 20-40 | | | | |
| 0-20 | 1 | 7 | | 8 |

**Fast Shot Velocity for Cavity2**

| Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|
| Minimum | | Median | | Maximum |
| 90 | 90 | 105 | 120 | 120 |

Q3 & Q4: Optimal; Range: Top 50%, [>105 & <=120]; Strength: 3.1;
Q1: Avoid; Range: Bottom 25%, {>=90 & <=90}; Strength: 3.1; No. o
Q1 & Q2: Avoid; Range: Bottom 50%, [>=90 & <=105]; Strength: 3.1

| Penalty | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|
| 80-100 | 13 | 4 | | 3 |
| 60-80 | | | | |
| 40-60 | 1 | 1 | | 2 |
| 20-40 | | | | |
| 0-20 | 1 | 5 | | 10 |

The report also suggests that Cavity Prefill is optimal in its Top 50% range i.e. [>22 & <=40] and has more chances of reducing the Porosity Score in Cavity2 (Figure below shows the pattern) and has no effect on the Porosity Score in Cavity1.

**Cavity Prefill for Cavity2**

| Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|
| Minimum | | Median | | Maximum |
| 6 | 6 | 22 | 40 | 40 |

Q3 & Q4: Optimal; Range: Top 50%, [>22 & <=40]; Strength: 3.4;
Q1: Avoid; Range: Bottom 25%, {>=6 & <=6}; Strength: 2.9; No. o
Q1 & Q2: Avoid; Range: Bottom 50%, [>=6 & <=22]; Strength: 3.4

| Penalty | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|
| 80-100 | 12 | 5 | | 3 |
| 60-80 | | | | |
| 40-60 | 2 | 1 | | 1 |
| 20-40 | | | | |
| 0-20 | 1 | 4 | | 11 |

These combinations of settings do not appear in the original experiment, but p-matrix's unique data visualization method identifies ideal settings quickly and reliably.

**Conclusions:** p-matrix ensures that data is used optimally and the analysis picks out the real behaviour occurring in the process, not just based on averaging results. It displays them in a format that can be implemented in your foundry. For more information, visit us at www.7Epsilon.org.