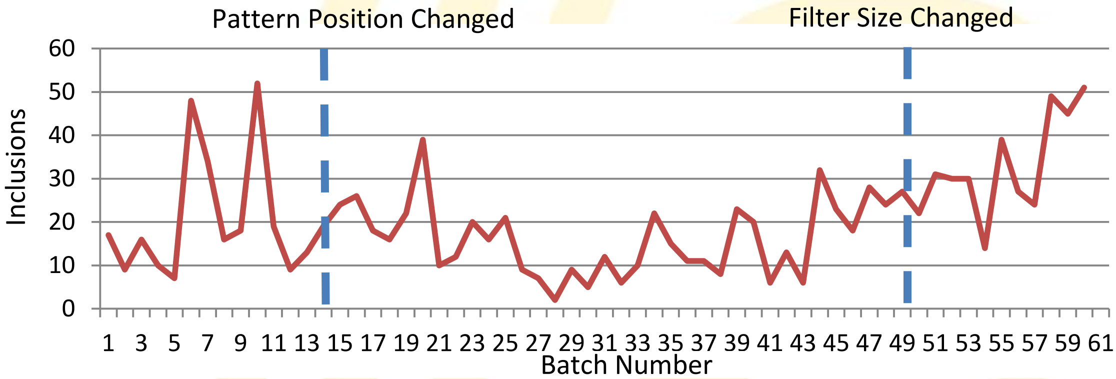
Example 4 - High Pressure Sand Moulding Parameters & Inclusions (Gray Cast Iron)

This example shows the effective use of the p-matrix Data Visualizer 2013 software to develop process control improvements for reduction in process variation in a precision sand casting foundry with a high pressure moulding facility.

The Problem: The sand casting foundry found that the number of castings rejected due to Sand Inclusions defects had increased to an unacceptable level. The process experts have identified discrete and continuous parameters in the process which may have an effect, and have also logged design/process changes made. The parameters recorded are shown in the table below.

Discrete Parameters	Continuous Parameters			Design / Process Changes
Date	Pouring Time	AFS No.	Permeability	Pattern Position
Operator	Pouring Temp	GCS	% Moisture	Filter Size
Shift	Pouring Sequence	Loss on Ignition	Return Sand Moisture	
Cavity	Hardness	Active clay	Prepared Sand Temp	
Furnace	C.E. Value	Compactability	Liquid Metal Wt per Box	

Process data is recorded over 2 months and is linked to the number of defective castings via batch number, date and shift. Process changes are recorded in a time series plot with Inclusions per production batch for 60 batches in the Figure below.



Aim: To visualize how any of the above parameters and their settings contribute to the variation in Sand Inclusions so that alterations to the process can be made to achieve robust process design.

The Solution: The production data with continuous, discrete sand parameters and process changes can be easily analysed using p-matrix Data Visualizer software. Its unique data visualization method discovers hidden trends in process settings that give the best chance making the perfect part, and highlight which changes to the process have the greatest and most positive effect.

Penalty Function for Inclusions: The analysis penalises the deviation from desired response values depending upon severity. p-matrix software applies 0 penalty value to desired response (batches below 20% Inclusions rate) , 100 penalty value to undesired response (i.e. batches having above 30% Inclusions rate) and linearly scales values for the remaining batches from 1 to 99.

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p-matrix Report: p-matrix discovered optimal settings of multiple parameters to reduce the Sand Inclusions defect. The 7Epsilon Quality Control meeting examined the following plan.

Confirmation Trial Plan: The report indicates low Compactability, high Loss on Ignition, higher AFS No. and high Prepared Sand Temp as major causes for Inclusions in the casting. It suggests that the key control variable Compactibility must be in its top 50% range (i.e. 39 to 43) to reduce chances of Sand Inclusions. Using a lower AFS No./grain size (i.e. bottom 50% values of 50 to 52.06) together with lower Prepared Sand Temp (i.e. bottom 50% values of 35°C to 38°C) will improve compactability. Bottom 50% range of Loss on Ignition values i.e. of 5.3 to 5.4 is also optimal. Also Pouring Sequence of 1 and 2 is better than 3 and 4 and top 25% of Liquid Metal Wt per Box should be avoided. The trends are consistent with the domain knowledge in the literature.

Compactability

Q1	Q2	Q3	Q4	
Minimum		Median		Maximum
38	39	39	40	43

Q3 & Q4: Optimal; Range: Top 50%, [>39 & <=43]; Strength: 3.1;
Q1: Avoid; Range: Bottom 25%, {>=38 & <39}; Strength: 2.9; No.
Q1 & Q2: Avoid; Range: Bottom 50%, [>=38 & <=39]; Strength: 3

Penalty	Q1	Q2	Q3	Q4
80-100	2	7		3
60-80	1	2		
40-60				1
20-40	1	3		1
0-20	1	14		24

Loss on Ignition

Q1	Q2	Q3	Q4	
Minimum		Median		Maximum
5.3	5.4	5.51	5.65	5.8

Q1: Optimal; Range: Bottom 25%, {>=5.3 & <=5.4}; Strength: 3.1;
Q3 & Q4: Avoid; Range: Top 50%, [>5.51 & <=5.8]; Strength: 2.1; N
Q4: Avoid; Range: Top 25%, {>=5.65 & <=5.8}; Strength: 2.6; No. of

Penalty	Q1	Q2	Q3	Q4
80-100	2	1	3	6
60-80		2	1	
40-60		1		
20-40	1	1		3
0-20	15	7	10	7

AFS No.

Q1	Q2	Q3	Q4	
Minimum		Median		Maximum
50	51.61	52.06	52.3	53.1

Q1 & Q2: Optimal; Range: Bottom 50%, [>=50 & <=52.06]; Strength: 2.7;
Q3 & Q4: Avoid; Range: Top 50%, [>52.06 & <=53.1]; Strength: 2.7; No. o
Q4: Avoid; Range: Top 25%, {>=52.3 & <=53.1}; Strength: 2.8; No. of Inter

Penalty	Q1	Q2	Q3	Q4
80-100	2	2	2	6
60-80			2	1
40-60		1		
20-40		2		3
0-20	13	11	9	6

Prepared Sand Temp

Q1	Q2	Q3	Q4	
Minimum		Median		Maximum
35	38	38	40	42

Q1 & Q2: Optimal; Range: Bottom 50%, [>=35 & <=38]; Strength: 1.8;
Q4: Avoid; Range: Top 25%, {>=40 & <=42}; Strength: 2.5; No. of Inter

Penalty	Q1	Q2	Q3	Q4
80-100	2	2	2	6
60-80		2		1
40-60			1	
20-40		3	1	1
0-20	9	13	9	8

Evidence in the production data also suggests that the filter size was optimal before the change. Possible training opportunities were also identified for Sam and Chris as a result of the evidence that they may be performing an incorrect operation in Shift 2. They have an avoid interaction with avoid ranges of both AFS No. and Loss on Ignition.

p-matrix report examines robustness of tolerance range for each factor and highlights regions of concern in the tolerance limits. Using the above analysis the foundry was able to quickly identify complex relationships and lower the number of defective castings produced. For more information, visit us at www.7Epsilon.org.

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