PROCESS OPTIMIZATION USING METACAUSE

By

Dr. Hathibelagal Roshan

Presentation at the SFSA Management Meeting

April 8, 2010

What is Process Optimization

Process optimization is the identification and control of the input process parameters (Factors) to achieve the desired output (Response) in any process.

The most common goals are minimizing cost, maximizing throughput, and/or efficiency.

This is one of the major quantitative tools in industrial decision making.

OPTIMIZATION OF CASTING PROCESS

In foundry terms, a process is typically a set of equipment arranged, controlled, and operated in a particular way, to produce a casting. The product must meet certain specifications, such as a certain production rate, product quality, and cost.

When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints.

Metal Casting Process is not a single process, but has several sub-processes such as Pattern making, sand preparation, molding, melting, pouring, heat treatment, Cleaning and Finishing etc.

It is essential to understand what is meant by Optimizing each of the sub-processes.

It is also useful for a foundry to know the level of optimization of its each of the sub-processes.

What is required for Casting Process Optimization?

1. A good tool to analyze the data and determine whether the process is optimum or not. (Process Optimizer Software) MetaCause Process Optimizer is the tool

2. Expertise in the understanding the process and identifying the factors and responses relevant to the process. FPR (Factor-Process-Response) Diagrams for each of sub-processes in the foundries.

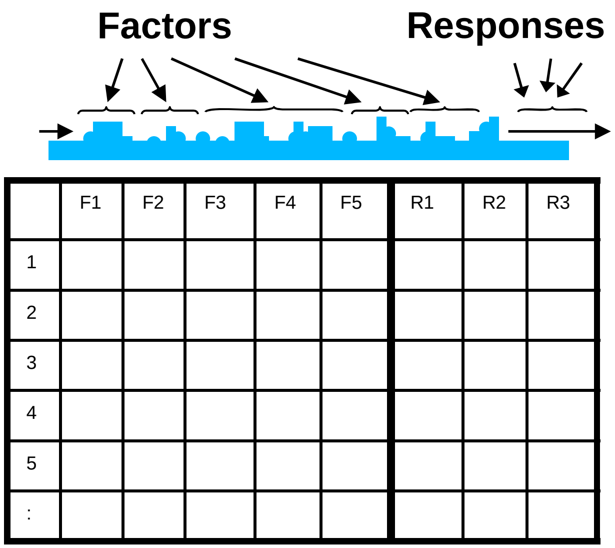
MetaCause® Software

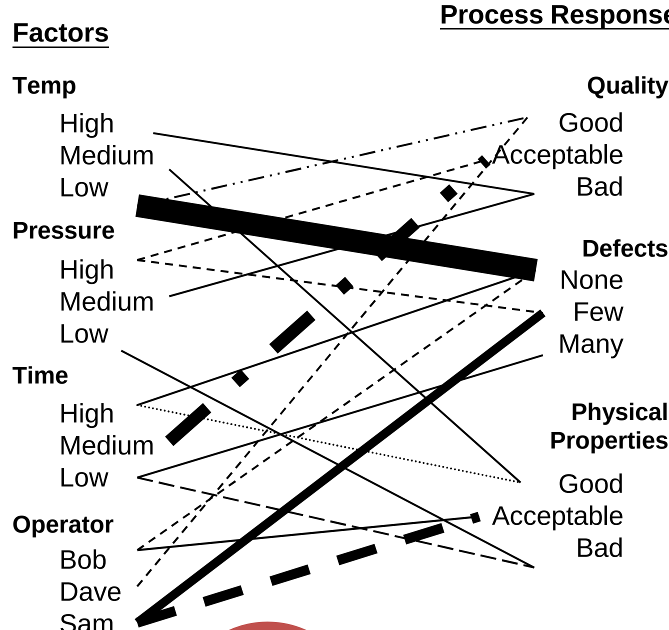
- MetaCause® is a data analysis software tool that gives you a check list on factor settings to achieve desired responses
- Process improvement software that uses historical data
- Self-learning software cuts waste and reduces costs across Industries
- Analyses multivariate data identifying relationships among variables

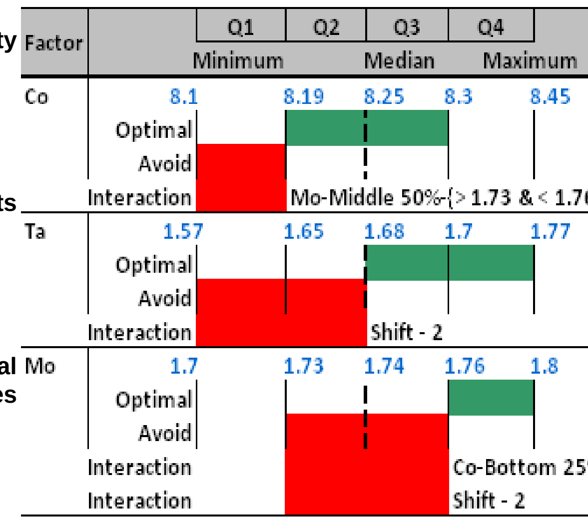
  -Main Effects

  -Interactions
- Inputs data in a very simple Excel format Outputs a checklist on factor settings as Optimal, Avoid or No Effect.

MetaCause® Software







Record Data

- Factors
- Responses
- Observations

MetaCause Analysis

- Discovers hidden trends
- Extracts true process behaviour
- Measures strength of links

Implement Results

- Main Effects & Interactions
- Optimal/Avoid settings
- Settings with No Effect

Sample Input Data

	A	B	C	D	E	F	G	H	I	J
1	BLANK DATA SHEET - STEEL		Factors/Responses given are for illustration purpose only. You do not need data for every factor liste							
2			Pour Date	1	2	3	4	5	6	7
3			Heat Number							
4		General data	Metal Code							
5			Furnace #							
6			Part #							
7		Discrete Paremeters	Melter							
8			Carbon Drop							
9			Tap Temperature							
10		Melting Parameters	Pouring Temperature							
11			Heat Size, Lbs							
12			Argon stir, minutes							
13			%C							
14			%Mn							
15			%S							
16	FACTORS (Xs)		%P							
17			%Si							
18			%Ni							
19			%Cr							
20			%Mo							
21		Chemistry	%Cu							
22			%Al							
23			%Ti							
24			Mn/S Ratio							
25			%Zr							
26			Zr- Yes/No							
27			%Ca							
28			%Ca/%Al ratio							
29			CE							
30		Heat Treat Parameters	Tempering Temperature							
31			UTS							
32			YS							
33			%EL							
34			%RA							
35			cvn at -40							
36	RESPONSES (Ys)		cvn at 0							
37		Properties	cvn at 70							
38			BHN on test block							
39			Fracture-Surface							
40			BHN on casting							
41										

Blank Data-Iron / Blank Data-Aluminum / **Blank Data-Steel** / Blank Data-Steel 2 / Cold Box Core Making / Sample [

Sample Input Data

A1 | fx | CVN at 70

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	CVN	Fractur	UTS	YS	Operator	Shift	Carbon Dr	CE	Pouring Te	Argon	%C	%Mn	%S	%P	%Si	%Ni	%Cr	%Mo	%Cu
2	57	0	143700	131600	Bob	1	59	0.66	2845	10	0.23	0.99	0.006	0.0095	0.4	1.8	1.15	0.55	0.11
3	56	0	148100	134700	Sam	2	64	0.68	2835	5	0.23	1.06	0.006	0.0165	0.6	1.7	1.28	0.57	0.12
4	42	0	124800	106400	Dave	2	75	0.66	2855	10	0.23	0.95	0.008	0.0223	0.6	1.8	1.22	0.57	0.1
5	55	4	131800	116600	Dave	1	35	0.64	2855	6	0.22	0.93	0.005	0.02	0.5	1.9	1.16	0.6	0.1
6	59	0	151200	141300	Bob	1	62	0.71	2825	4	0.26	1.11	0.008	0.0128	0.4	1.8	1.2	0.58	0.1
7	53	6	128000	111400	Sam	2	86	0.64	2841	4	0.21	0.99	0.008	0.0028	0.5	1.8	1.15	0.55	0.09
8	71	6	130100	117000	Chris	2	37	0.64	2851	6	0.22	0.95	0.007	0.002	0.4	1.8	1.18	0.57	0.08
9	56	0	140200	129600	Dave	3	52	0.66	2863	6	0.22	1.05	0.009	0.0016	0.5	1.7	1.23	0.55	0.13
10	66	0	122200	108100	Dave	1	63	0.62	2855	6	0.21	0.89	0.007	0.0024	0.4	1.7	1.13	0.56	0.1
11	65	3	123700	109400	Sam	2	66	0.62	2857	6	0.2	0.96	0.098	0.0036	0.5	1.7	1.17	0.56	0.13
12	62	16	137200	125900	Chris	3	33	0.66	2855	6	0.22	1.06	0.009	0.0028	0.4	1.7	1.25	0.55	0.12
13	61	4	139600	129700	Dave	1	44	0.64	2865	10	0.22	0.94	0.011	0.0124	0.4	1.8	1.16	0.56	0.1
14	59	11	138100	126800	Dave	1	53	0.69	2845	5	0.25	1.06	0.008	0.0026	0.4	1.8	1.22	0.55	0.09
15	42	11	135200	121800	Sam	1	58	0.68	2855	8	0.23	1.09	0.009	0.0043	0.4	1.8	1.28	0.56	0.1
16	49	6	151000	138900	Chris	1	50	0.67	2865	4	0.25	0.96	0.008	0.0029	0.4	1.7	1.2	0.56	0.07
17	62	4	130800	117700	Dave	1	60	0.64	2865	14	0.21	0.98	0.007	0.0041	0.4	1.8	1.2	0.55	0.07
18	62	0	144100	128000	Dave	2	22	0.67	2823	6	0.26	0.94	0.006	0.0028	0.6	1.7	1.11	0.56	0.09
19	60	4	140300	129400	Dave	2	49	0.66	2855	5	0.23	1.01	0.008	0.0028	0.5	1.8	1.19	0.56	0.07
20	52	21	144900	128800	Dave	1	47	0.66	2855	6	0.23	1	0.011	0.0035	0.5	1.7	1.19	0.56	0.07
21	61	6	129900	115400	Dave	1	70	0.62	2855	6	0.2	0.94	0.01	0.004	0.5	1.8	1.17	0.56	0.06
22	73	0	117400	100400	Bob	1	55	0.64	2837	4	0.23	0.94	0.009	0.0045	0.5	1.7	1.09	0.57	0.09
23	40	9	142500	130200	Sam	2	16	0.68	2860	6	0.25	0.98	0.01	0.0049	0.5	1.7	1.19	0.59	0.1
24	89	0	119800	110000	Chris	2	74	0.62	2837	6	0.21	0.96	0.007	0.0021	0.4	1.7	1.08	0.58	0.12
25	62	0	142700	132700	Dave	1	42	0.65	2855	6	0.21	1.04	0.009	0.0029	0.4	1.7	1.22	0.56	0.09
26	61	6	136300	124400	Bob	1	40	0.63	2866	6	0.2	1	0.009	0.0032	0.5	1.8	1.15	0.55	0.09
27	54	9	148600	136200	Sam	2	28	0.66	2880	4	0.23	0.99	0.008	0.0037	0.5	1.7	1.2	0.56	0.09
28	56	16	144600	133600	Chris	2	49	0.61	2870	4	0.2	0.92	0.009	0.0028	0.5	1.7	1.17	0.55	0.11

Data - Equal Sample Rate | Factor Data - High Sample Rate | Example - E

MetaCause Report

MetaCause Process Optimizer 2008 - D:\January 2010 R4.7 Exe\MetaCause Examples\Investment Casting\MetaCause R4.7 Investment C...

File MetaCause View Help

File Open Run Report Save Report

MetaCause® - Committed to discovering main effects and interactions

MetaCause Optimisation Report

Input File Name: D:\January 2010 R4.7 Exe\MetaCause Examples\Investment Casting\MetaCause R4.7 Investment Casting.xls

Date and Time of Report Generation: 16 January 2010 20:04:26

Legend

Factor/Attribute Level Classification	Interpretation
Avoid	Increases risk of achieving unacceptable response. Demonstrates correlation with high (>= 50) penalty value observations.
Optimal	Reduces the risk and improves chances of realizing desired response. Demonstrates correlation with low (<= 30) penalty value observations.
No Effect	Does not change the risk level. No evidence of correlation is discovered.

Code	Interpretation
†	There is missing data for this factor in the input file.
‡	The missing data for this factor may have significant influence on the reliability of results predicted for this factor.
**	This response is also considered as a factor here.

Strength	Importance Measure
1	Useful to Know (Influential if the strength of interaction is > 2.5)
2	Important to Know (Influential if the strength of interaction is > 2.5)
2.5	High
3	Considerably High
4	Highly Influential
5	Exceptionally Strong

Time Elapsed: 00:00:01

Summary Report

Response	Shrinkage (%)(LB)
Lower Threshold Value	20
Higher Threshold Value	30
No. of Observations	60

Factor / Attribute	Ranking		Q1	Q2	Q3	Q4
			Minimum		Median	Maximum
Prepared Sand Temp			35	38	38	40	42
		Optimal				
		Avoid				
		Interaction			%Si-Middle 50%-{> 2.2 & < 2.4}	
		Interaction			%C-Bottom 50%-[>=3.3 & <=3.5]	
		Interaction			AFS No.-Bottom 50%-[>=50 & <=52.06]	
		Interaction				Weekday1-
		Interaction				Shift-2
Compactability			38	39	39	40	43
		Optimal				
		Avoid				
		Interaction			AFS No.-Top 50%-[>52.06 & <=53.1]	
		Interaction			Shift-2	
Shift						
1	1	Optimal				
		Interaction %C-Bottom 50%-[>=3.3 & <=3.5]				
		Interaction Green Compressive Strength (GCS)-Middle 50%-{> 1925 & < 1975}				
		Interaction %Mo-Top 25%-{>= 0.02 & <= 0.03}				
2	2	Avoid				
		Interaction Compactability-Bottom 50%-[>=38 & <=39]				
		Interaction AFS No.-Top 50%-[>52.06 & <=53.1]				
		Interaction Prepared Sand Temp-Top 50%-[>38 & <=42]				

LIMITATIONS OF DOE

1. In the DOE, the number of experiments needed depends on the number of factors. The number of factors in casting process are generally high.
2. In the DOE, there is a need to carry out controlled experiments to collect the required data and it could interrupt regular production.
3. In the DOE, the level of factors have to be with a considerable difference in order to have meaningful results.
4. The DOE assumes known distributions to the unknown foundry processes, as such the results could be biased.
5. The DOE requires people with a reasonable expertise in the use to statistical techniques to design and interpret the results.

TECHNOLOGY GAP IN FOUNDRY INDUSTRY

1. Data
2. Information : Processed Data
3. Knowledge : Actionable Information

- MetaCause Process Optimizer analyzes foundry data and provides actionable information
- FPR (Factor-Process-Response) diagrams provide the necessary knowledge relating to the various sub-processes in the foundry industry
- The intent is to give foundries the knowledge to evaluate their sub-processes and determine the level of their optimization and their impact on profitability.

FPR (Factor-Process-Response) Diagram
Steel Melting Process

Boundary: Melting to Heat Treatment to Testing the Properties of Test Block.

X's
Factors

1. %C(X1)
2. %Mn (X2)
3. %Si (X3)
4. %S (X4)
5. %P (X5)
6. %Ni (X6)
7. %MoX7)
8. %Al (X8)
9. %N(X9)
10. %Zr (X10)
11. %Ti (X11)
12. Mn/S ratio (X12)
13. Ca/Al ratio (X13)
14. Tempering Temp (X14)
15. Tempering Time (X15)
16. Quench after tempering (X16)
17. Size of Test Blokc (X17)
18. Location of test (X18)
19. BHN of Test Block (X19)
20. Melter (X20)
21. Pourer (X21)
22. Heat Treat Operator (X22)

Steel Melting Process

Y's
Responses

1. Tensile Strength, %,Y1
2. Yield Strength Y2
3. % Elongation Y3
4. % Reduction in Area Y4
5. BHN of Test Block Y5
6. Charpy value at –40F, Y6
7. Charpy value at 0F, Y7
7. Charpy value at 70F, Y8
8. % of Conchoidal Fracture, Y9

SUMMARY