Green Sand Additives, Molding and Data Analytics,

ANKIROSS 2016

Istanbul TURKEY

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Moving from an era of 'Art' to the futuristic 'Science' of Green Sand Molding

The Maxim - 'Art of Green Sand molding' - presupposes:

- Art is the preserve of the 'artist', of which there are an increasingly decreasing number.

Along the way, However, **Modern Foundry** has long since graduated to **a very exact science**:

- The dimensional and metallurgical accuracy of the casting is a precise outcome of:
  - Computer software simulated design & methoding
  - Highly automated and precise molding machines.
  - Sophisticated & increasing targeted measurements of microstructure

The Transformation by Data Science

- The world is being transformed by the power of data science.
  - An increasing part of our everyday lives and business eco-systems are being transformed using data analytics
  - GE uses data analytics to save fuel – almost 6%
  - Predictive analytics predicts turbine failure much before expensive failure.
- So why not foundry processes?
- So why not the biggest **Blind Spot** in Foundry processes :
  - **Sand Molding ?**

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The 'Blind' Spot

The 'Why' and the Solution

Data	Process Variability	Experiential Legacy		Blind spot		The Un-Met Need
▪ Huge volumes & only available in Multiple pockets ▪ Mostly Un-validated ▪ Almost always Un-co related	▪ Product mix ▪ Multi-Variate cause and effect relationship ▪ 20^{20} probabilities: 20 sand parameters to 20 defects classification	▪ Shrinking pool of Domain experts ▪ Loss of experiential legacy due to attrition ▪ Non-annotated legacy events	= Reactive decision making to resolve rejections = Repetitive rejections = Repetitive losses			Modern Data predictive analytics to convert decision making from Reactive to Proactive, forward looking actions.

Globally, all foundries suffer casting rejections.

Some suffer more, some less.

- Rejections are repetitive. So, losses are repetitive.
- Rejections could range from 0.5% to 20%.

Back-of-the-envelope calculation:

the cost of a

1%

Green sand Rejection ...

...in an entry-level

24,000

ton/annum foundry...

...is approx. US$

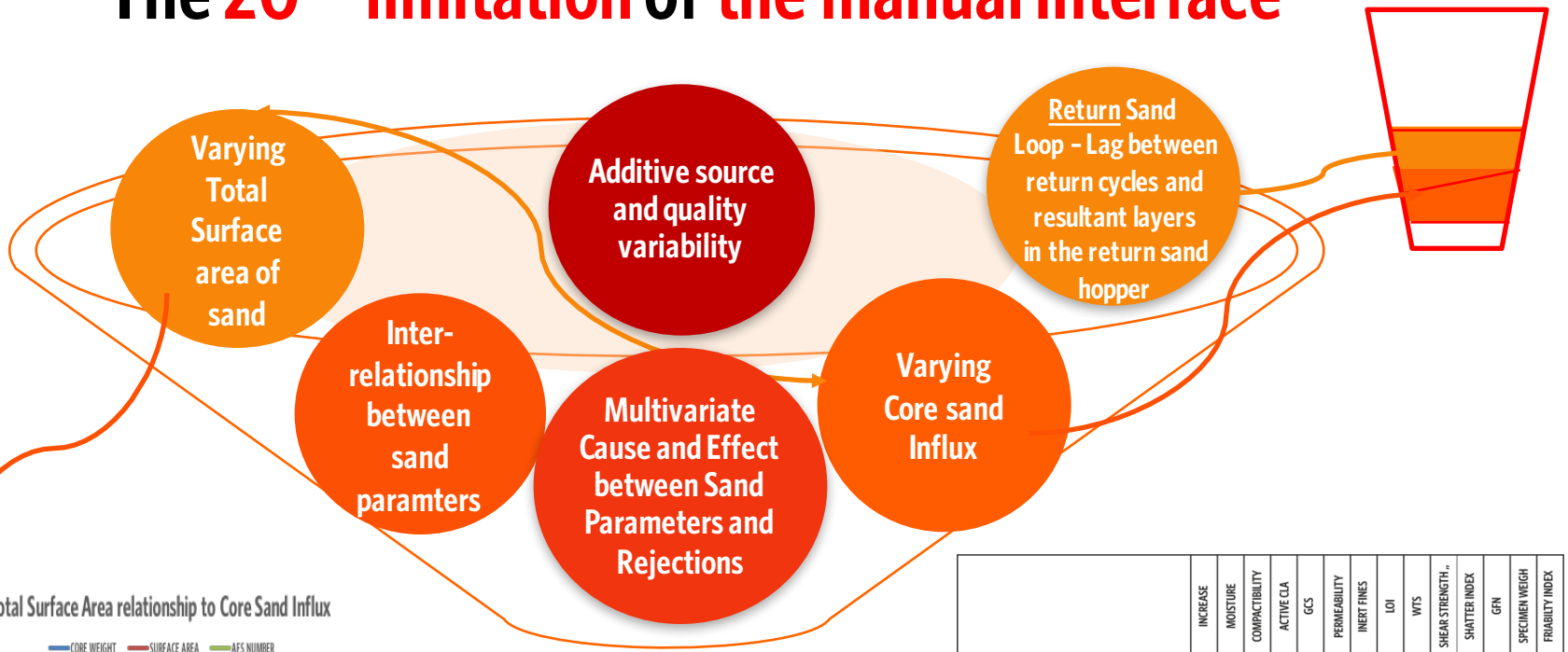
$220,000

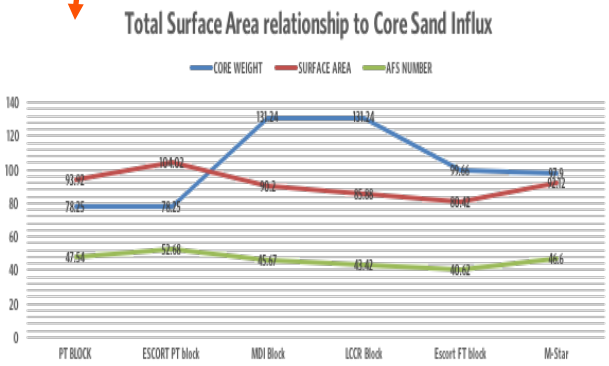
per annum

Given the molding process dynamics, defects are inevitable:

- Pattern Changes
- Varying core sand influx
- Varying Sand : Metal ratios
- Varying Core Sand GFN to Molding Sand GFN
- Fixed-dose, prophylactic or approximately variable addition of additives
- Varying additive quality – validated for precise KPIs – in some geographies
- Non or semi annotated changes in process, input materials, machines, sources of supply
- Non availability of on-line Measurement of sand properties.
- Muted legacy of Return sand measurements

The 20[20] limitation of the manual interface





	INCREASE	MOISTURE	COMPACTIBILITY	ACTIVE CLA	GCS	PERMEABILITY	INERT FINES	LOI	WTS	SHEAR STRENGTH „	SHATTER INDEX	GFN	SPECIMEN WEIGH	FRIABILITY INDEX
Temper MOISTURE	↑		↑	X	↑	X	X	X	↑	↑	↑	X	↓	↓
ACTIVE CLAY	↑	X	↑		↑	↓	X	X	↑	↑	↑	↓	X	↑

Input material / SETTING	INCREASE	GCS	SHEAR STRENGTH	SHATTER INDEX	MOISTURE %	WET TENSILE STRENGTH	PH Value	PERMABILITY	SPECIMEN WEIGHT	COMPACTABILITY	FRIABILITY	L O I	V M	ACTIVE CLAY	INERT FINES	AFS No.
SODIUM BASE BENTONITE	↑	↑	↑	↑	0	↑	↑	↓	↑	↑	0	X	X	↑	0	X
LUSTRUS CARBON ADDITIVE	↑	↓	↓	↓	X	↓	↓	↑	↓	↑	↑	↑	↑	X	X	0
FINE SILICA SAND - HIGH AFS NO.	↑	0	0	0	0	0	X	↓	↑	0	0	X	X	X	X	↑

Impact on casting defects

Reactive Decision making in absence of decision support

The additive inter-relationship matrix

- All the parameters that we test in green sand (and those we don't as yet) have a cause and effect inter- relationship.

Two examples of how one parameter change can impact 8 different properties of the molding sand

	INCREASE	MOISTURE	COMPACTIBILITY	ACTIVE CLA	GCS	PERMEABILITY	INERT FINES	LOI	WTS	SHEAR STRENGTH „	SHATTER INDEX	GFN	SPECIMEN WEIGH	FRIABILITY INDEX
Temper MOISTURE	↑		↑	X	↑	X	X	X	↑	↑	↑	X	↓	↓
ACTIVE CLAY	↑	X	↑		↑	↓	X	X	↑	↑	↑	↓	X	↑

LEGEND

Direction	
Increase	
Decrease	
No Change	
Likely	

The cause and effect relationship matrix

Input material / SETTING	INCREASE	GCS	SHEAR STRENGTH	SHATTER INDEX	MOISTURE %	WET TENSILE STRENGTH	PH Value	PERMIABILITY	SPECIMEN WEIGHT	COMPACTABILITY	FRIABILITY	L O I	V M	ACTIVE CLAY	INERT FINES	AFS No.
SODIUM BASE BENTONITE	↑	↑	↑	↑	0	↑	↑	↓	↑	↑	0	X	X	↑	0	X
LUSTROUS CARBON ADDITIVE	↑	↓	↓	↓	X	↓	↓	↑	↓	↓	↑	↑	↑	X	X	0
FRESH SILICA SAND - HIGH AFS NO.	↑	0	0	0	0	0	X	↓	↑	0	0	X	X	X	X	↑

LEGEND

Direction	
Increase	
Decrease	
No Change	
Likely	

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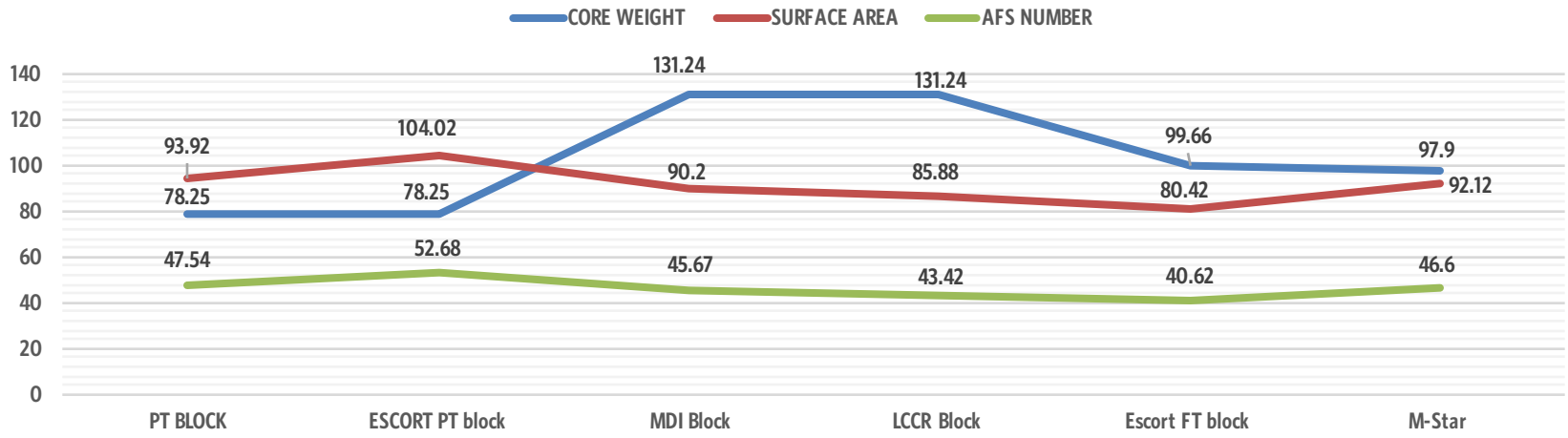
Total Surface Area relationship to Core Sand Influx
Impact on Varying Additive demand



With the Return Sand Hopper having different layers of sand:

- **In above study: Each Marker represents the return sand of a specific pattern.**
- **Raw Core Sand GFN is lower than that of the Raw Molding Sand**
- **The chart above shows that as the core sand influx increases, the TSA decreases and vice versa.**

- **Reasoning: each pattern return sand will form a layer as it re-circulates into a storage hopper.**
- **The TSA of sand layer that will come through for the next molding batch mix can only be estimated if at all**
- **The motivation is to examine the variability of the TSA of the sand before it goes into the mixer.**
- **The variability will decide how much make-up additives are required to achieve target properties.**

- **In absence of data analytics even variable additions can at best be approximate.**
- **Under-dosing or overdosing of the additive/s will also decide the rejection legacy**
- **The 20^{20} limitation of the human interface**

Motivation for Data Analytics decision support

- To graduate from reactive decision making in targeting optimal sand properties in terms of controlling related rejections
- To move towards process consistency: reducing the system 'noise' by predicting and then optimizing the optimal target sand parameters
- To move towards 'dose-by-need', variable additions of additives. Prevent overdosing and under-dosing the system sand. Optimizing consumption.
- Thereby control, mitigate or reduce rejections .

SANDMAN Analytics and SandMIX Analytics terms briefly explained

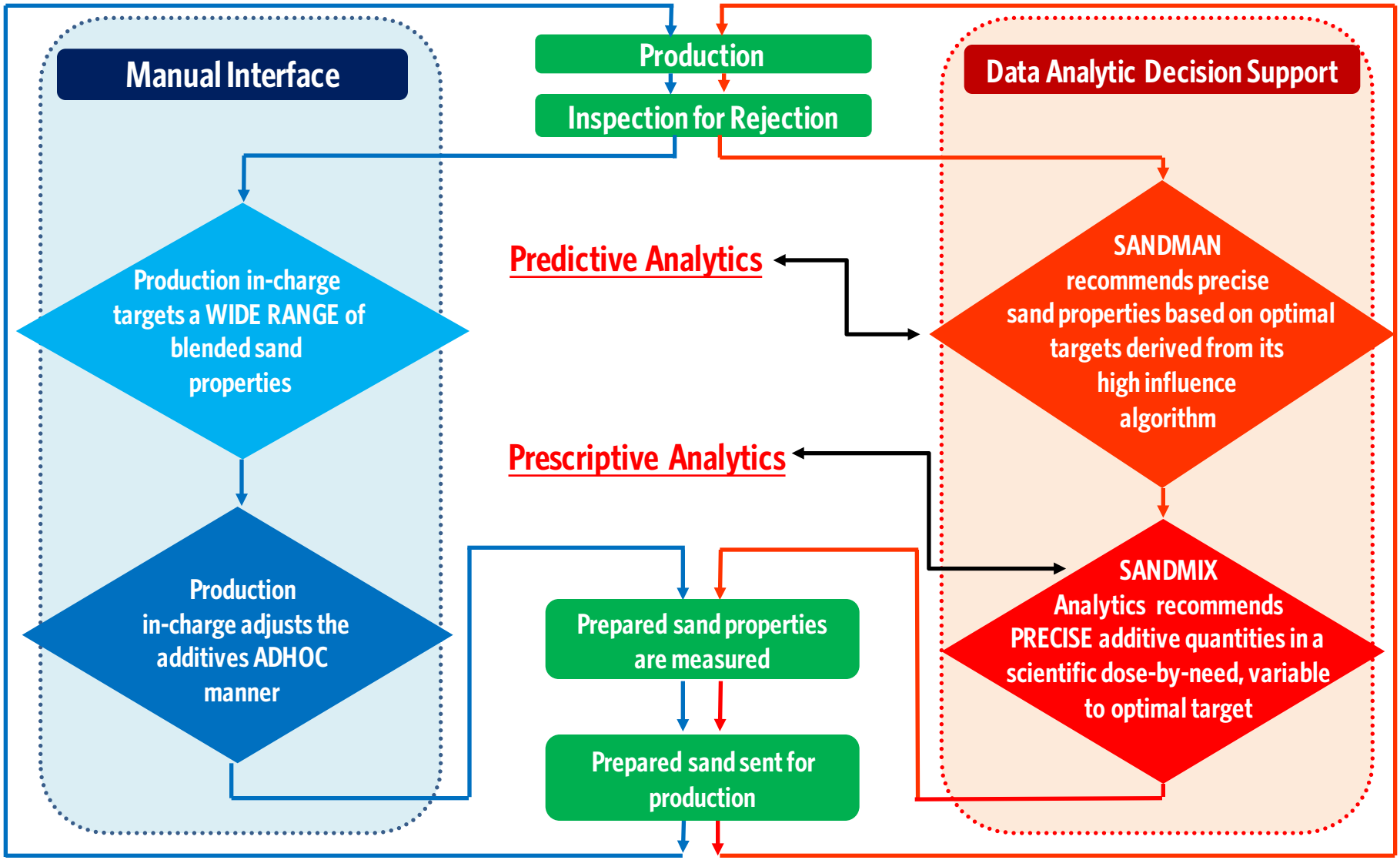
SANDMAN

- Is the algorithm which **predicts** the optimal target properties of the sand parameters to achieve dynamically consistent process consistency.
- It then provides **directional** predictive decision support for high influencing parameters impacting rejections for the day..
- Its "Where" to look and go!

SandMIX analytics

- Translates the SANDMAN optimal targets by **prescribing** the **QUANTITIES** of sand additives to be added to go from the day's return sand properties to the target optimal sand properties.
- It's How to get there!

Manual V/s Data Analytics - Workflow



Setting the Context between the Manual and Analytics Interface

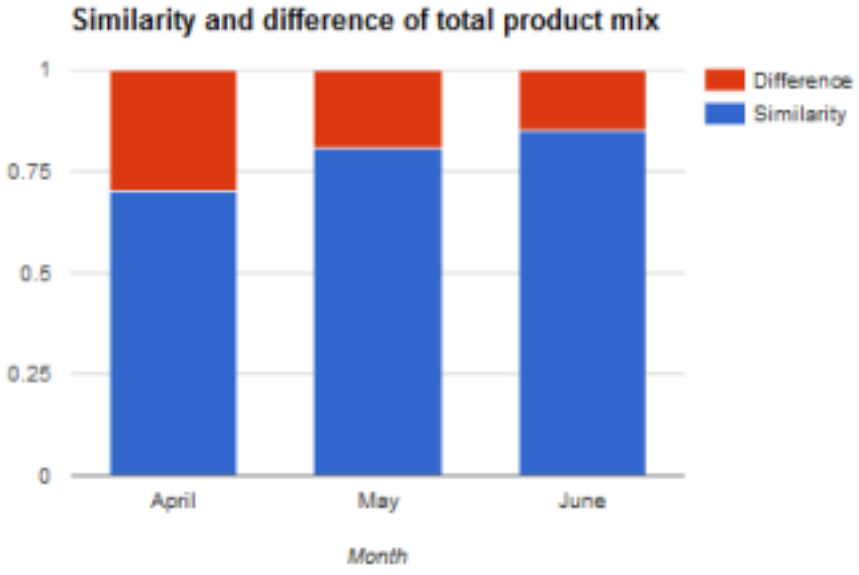
Case Study

Using Data Analytics to reduce effects of casting

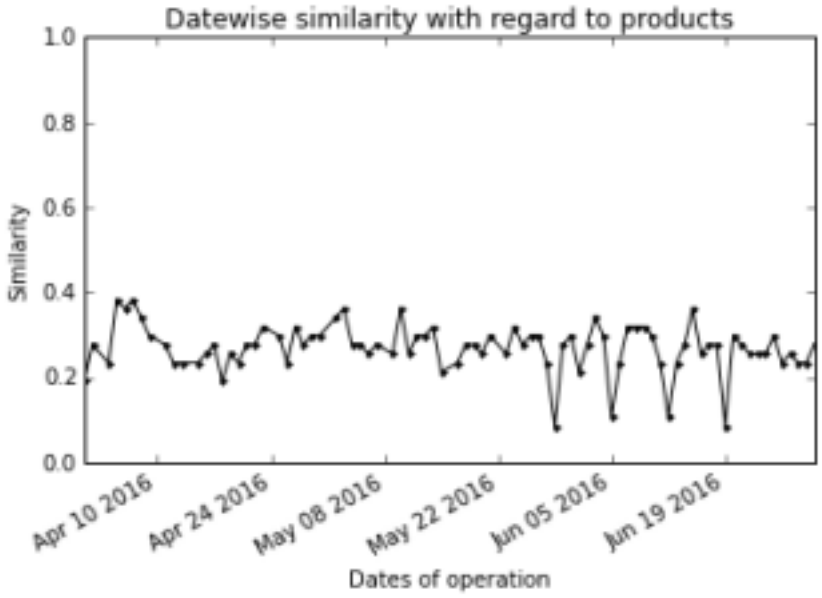
Component Mix Variations

- Prophylactic additions **inevitably pay** little regard to the **varying product mix** resulting in varying TSA and demand for additives
- Daily and monthly quantification of the **dissimilarities of casting product mix** and quantities provides understanding of the production complexity
- Over **long and continuous data sets**, confidence increases in reducing day-to-day biases of the Pattern, additives, sand properties variations and their effects on the system sand.

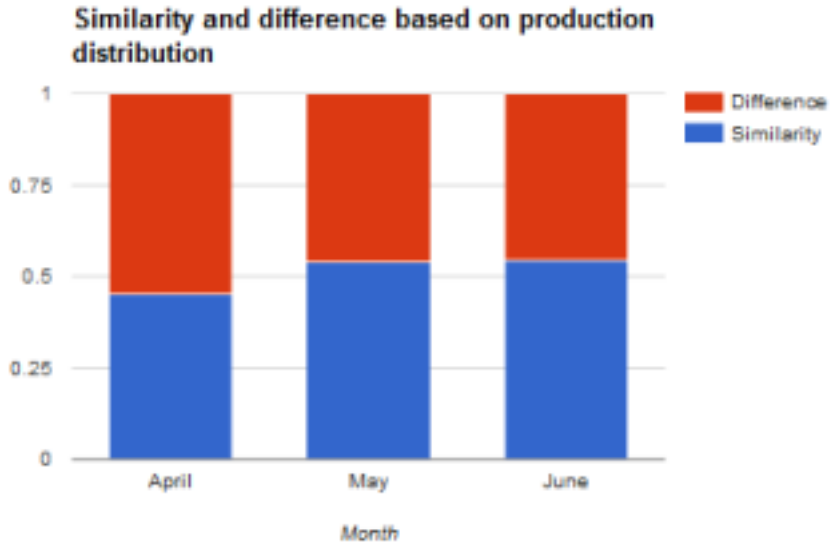
Only similar components are produced every day, irrespective of the quantity of production



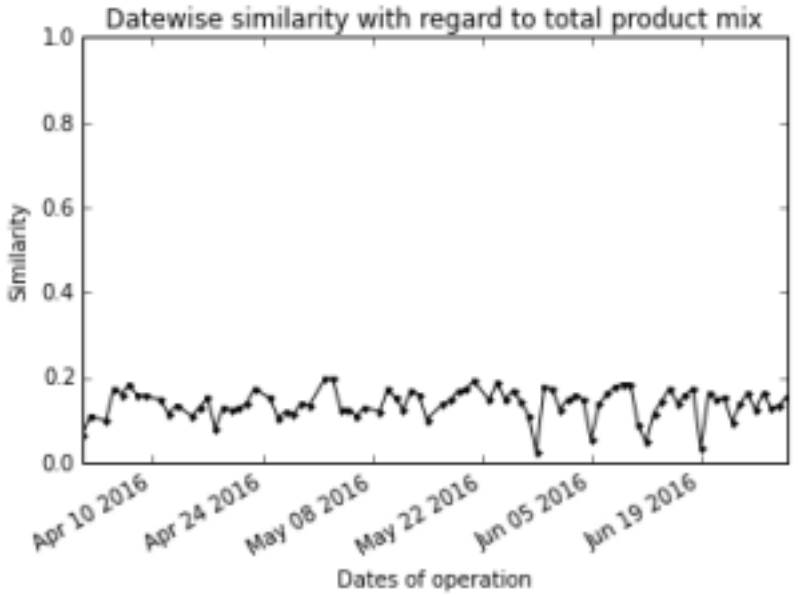
Products mix gets dissimilar at the day level



Dissimilar components are produced every day in varied quantities - Jobbing foundry



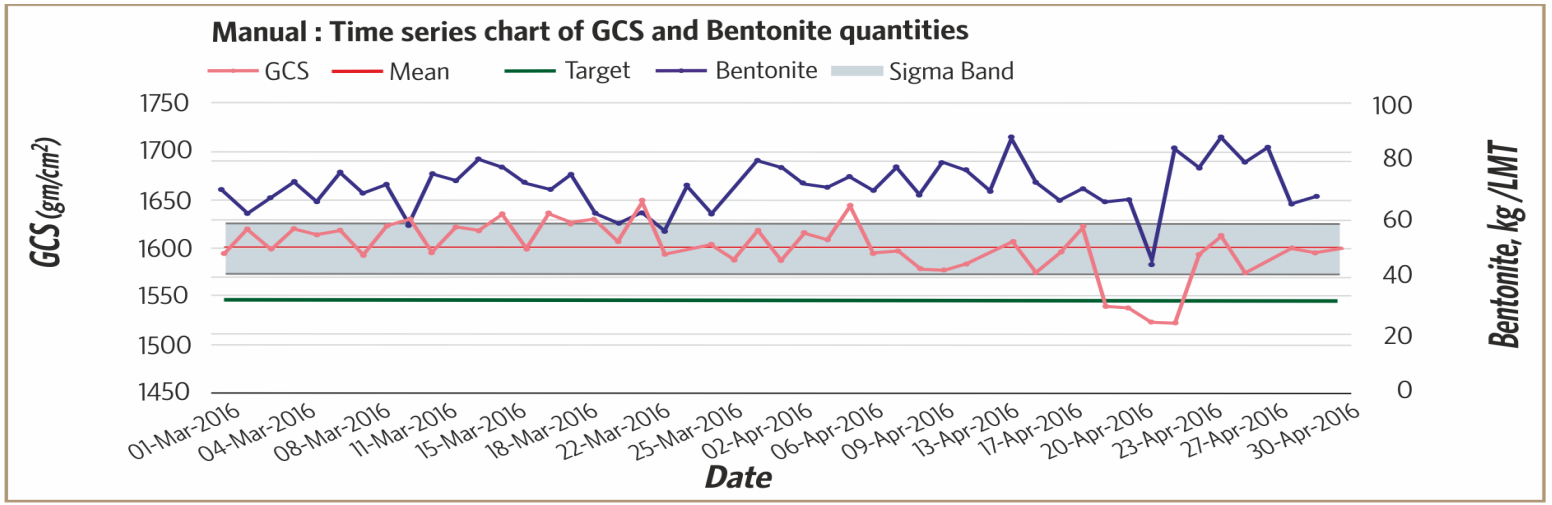
Products mix gets dissimilar at the day level

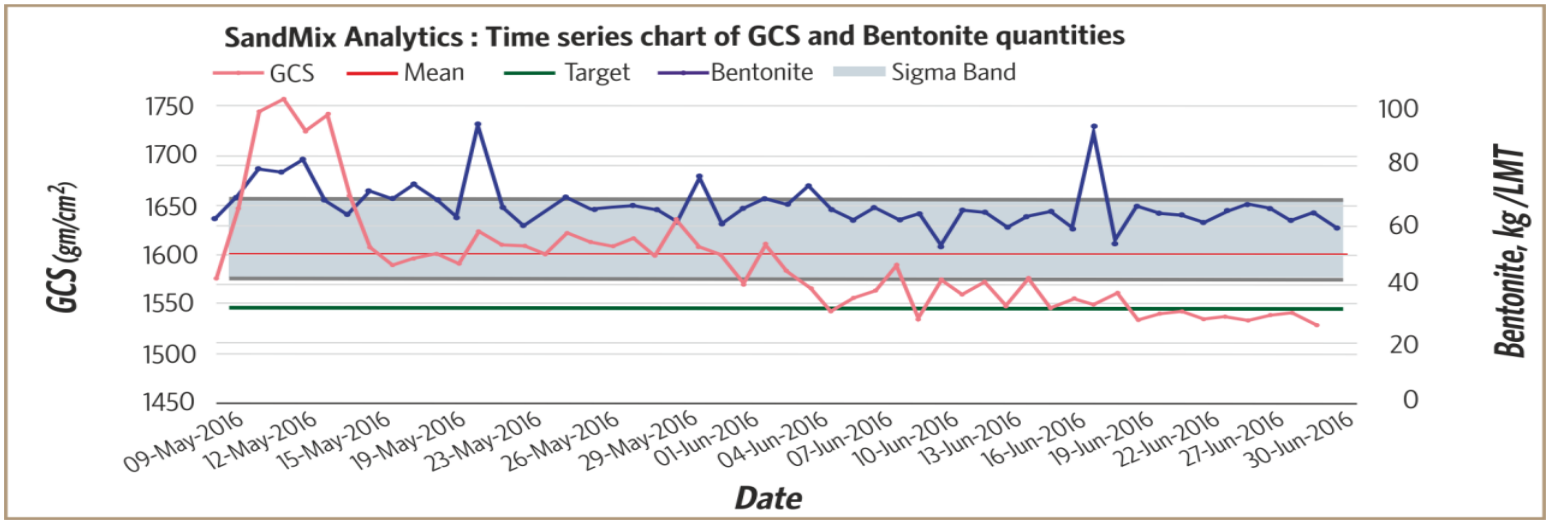


Setting the context : Manual V/s Prescriptive analytics

1. Manual: GCS shows moving away from the green line (optimal). The noise is apparent.
2. SandMIX analytics: GCS is now closer to optimal Plant has operated based on SandMIX advisory.

Benefits : Rejections (refer to rejections chart) ... Consumption reduction (refer to bentonite chart)





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Foundry has used SandMIX as baseline and refined their judgement to improve surface finish by Systematic and planned excursions into increasing GFN

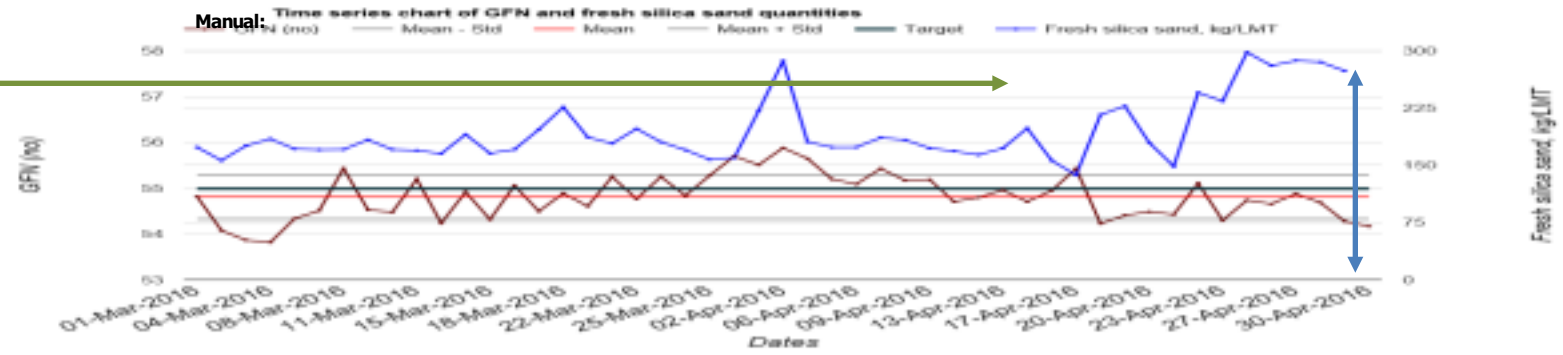
Setting the context :

1. Manual: the FSS additions are severely inconsistent.

2. SandMIX advisory : The FSS additions have reduced due to variable additions and the foundry could experiment with increased GFN to obtain better surface finish without compromising the consistency of the FSS additions.

Benefits : Rejections (refer to rejections chart) ... Consumption reduction (refer to Fresh Silica Sand (FSS) chart)

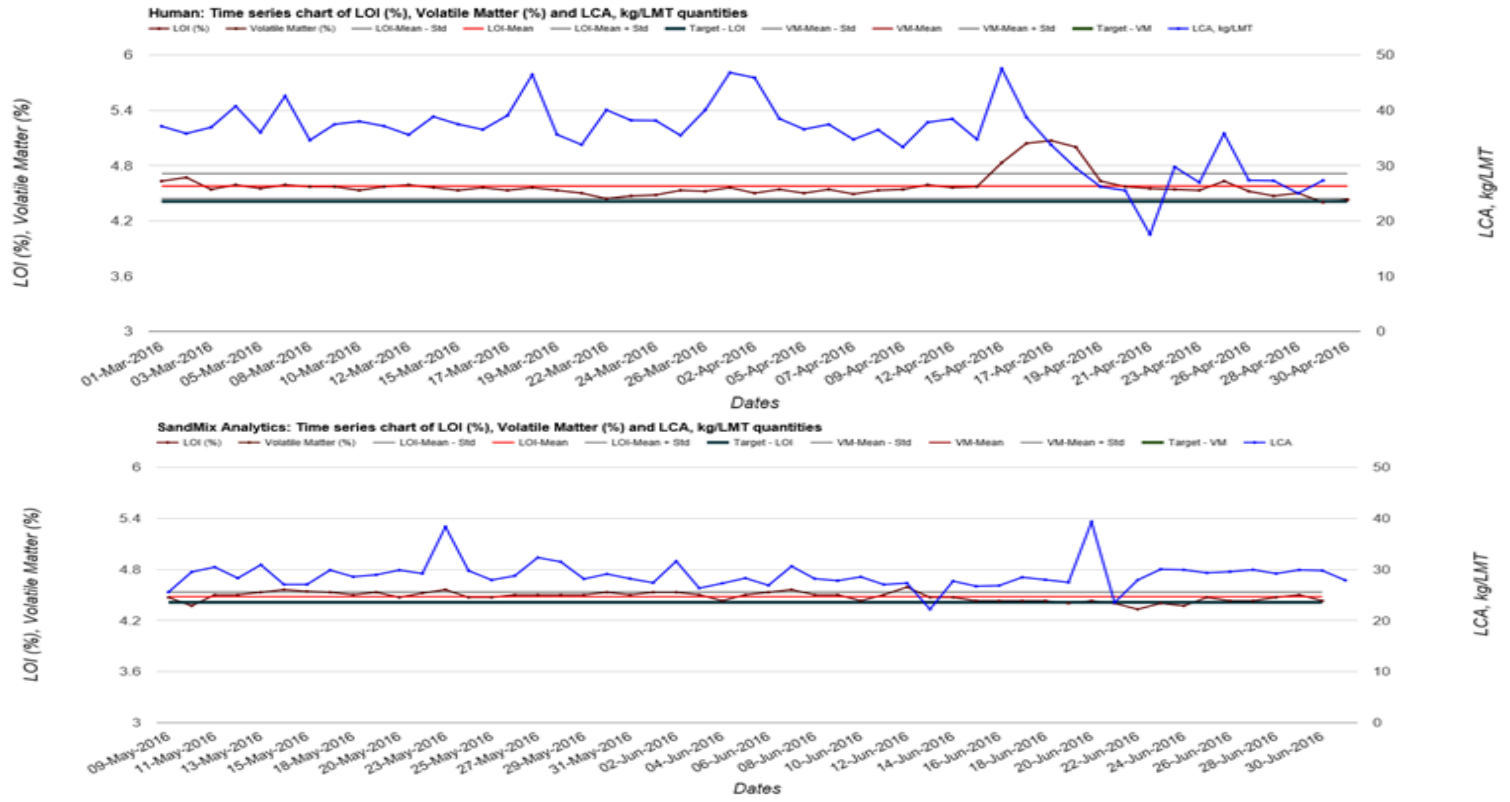
Manual:



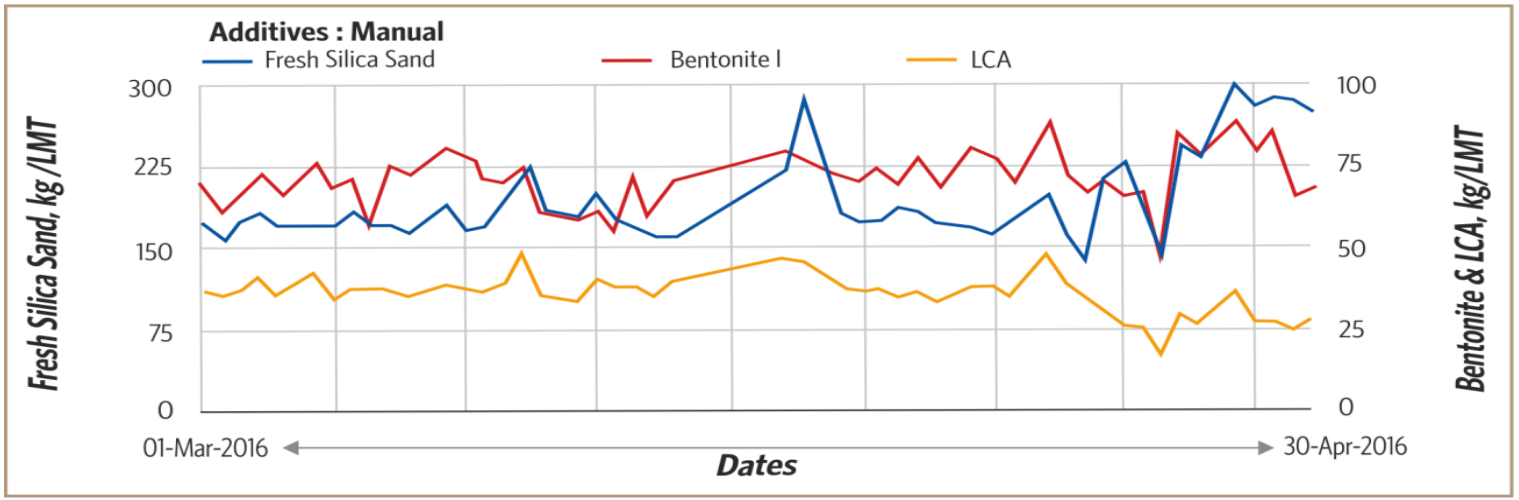
Setting the context : Manual V/s Prescriptive analytics

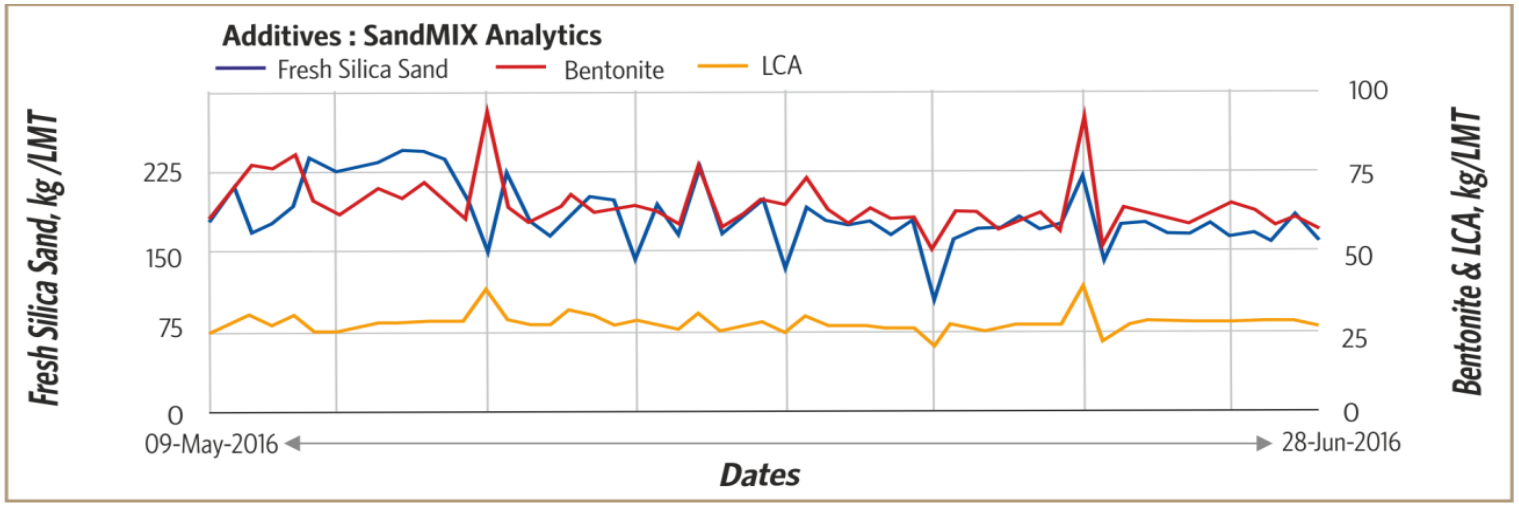
1. Manual: Lustrous Carbon Additives (LCA) shows away from the green line (optimal). The noise is apparent.
2. SandMIX analytics: LCA is now closer to optimal Plant has operated based on SandMIX advisory.

Benefits : Rejections (refer to rejections chart) ... Consumption reduction (refer LCA chart)



VARIABLE "DOSE-BY-NEED" ADDITION ADVANTAGE OF PRESCRIPTIVE ANALYTICS

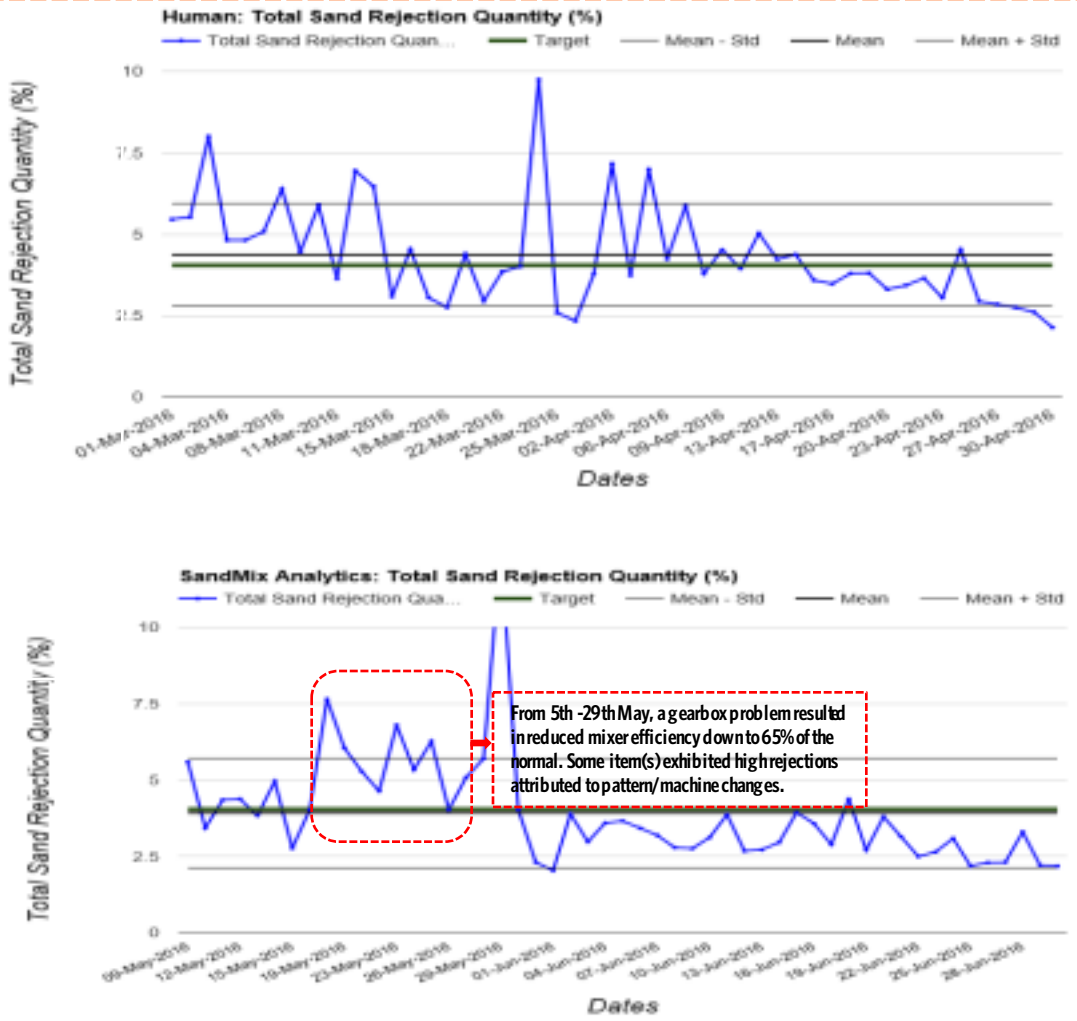




And why did rejections and casting performance improve?

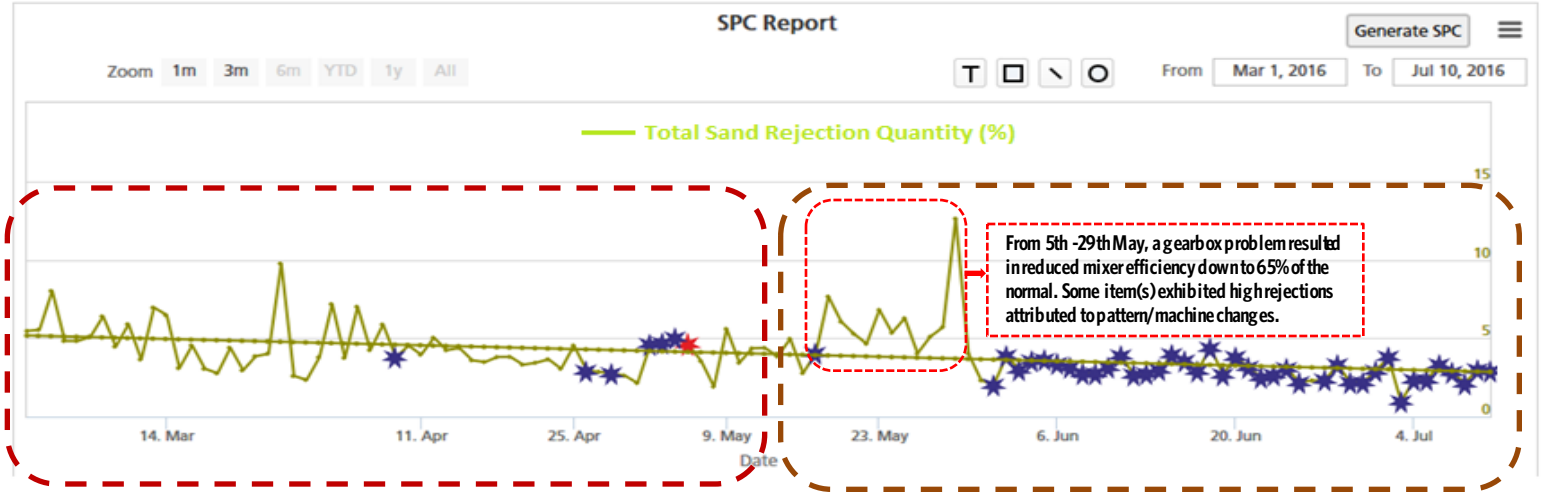
Control of sand properties

- The achievement of optimal target sand property values (read optimal as consistent and low rejections)
- Dose by need variable addition of additives



Results from case study - Rejections

	Apr-2016	May-2016	Jun-2016
Total Sand Rejection as % of Total Production by weight	4.23 %	4.60 %	3.14 %



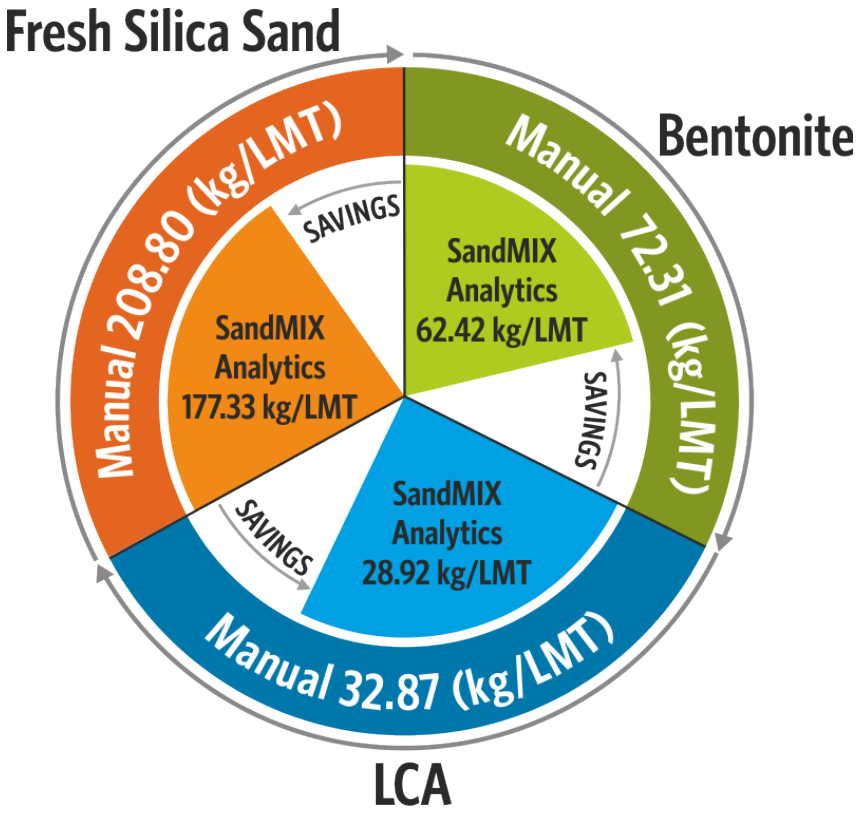
Manual control

SandMix Analytics

Why did the additive consumption levels reduce during the trials?

- SandMIX analytics provides systematic advisory, dose-by-need, on the quantities of additives to be manipulated
- Each additive prediction was variable and dependent on the past state of the sand plant, unlike the domain approach **which was dependent only on the prepared sand properties to be achieved with little regard to the enrichment or deficit of additives in the recirculated sand**
- This approach had resulted in reduction of additives consumption as an added benefit

Manipulation of additives and **reduction** in consumption



Enhancing the power of the Human Interface

- Data Science is a "decision support" tool for control.
- The functionality and efficiency of the Human resources is hugely enhanced when:
  - Decisions are un-encumbered by reactive thought.
  - Predictive analytics enable decision making on forward looking bias.
- Excursions into uncharted areas and experiments for improvement can be planned and taken with more confidence
  - knowing that each data point is building a decision support legacy
  - This legacy is being factored for forward and future decision support

MPM INFOSOFT and the **SANDMAN** Team wish to thank

ANKIROSS 2016 and the Turkish Foundry Industry for this opportunity to present the technology that promises to transform the way modern foundries will view their data for profits now and in the future!