Six Sigma-DMAIC Approach for Improving Quality of Sinter at Sinter plant

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Abstract: *Blast furnace uses Iron bearing material like Sinter (70%), Pellet (15%) and Calibrate Ore (15%) for producing Hot Metal. Sinter is produced in sinter plants and transported through a series of conveyors and stored in Blast Furnace stock house. Sinter size requirement for charging in Blast furnace is 5-40mm (Blast furnace feed) and deviations from range as required by Blast Furnace will cause the Sinter Plant Fines, which adversely influence smooth Blast furnace operation. Undersize fraction <5mm is called Sinter Return Fines, which is a rejection generated after screening in Blast Furnace stock house. It is sent back to Sinter Plant for re-cycling. One of the challenges of Quality Assurance is to ensure higher sinter proportion in Blast Furnaces. Sinter fines generation depends upon process parameters and number of falls in the transportation route. High rejection of blast furnace affects on the sinter yield.*

The main aim of this work is to identify and control the critical process parameters which are contributing to generation of higher return files by SIX SIGMA TOOLS through DMAIC Process. Apart from this the area where sinter degradation is more studied and improved.

Keywords: *Sinter Plant, Sinter Physical and Chemical Properties, Six Sigma, Statistical Quality Control*

I. INTRODUCTION TO SINTER PLANT

It is an Agglomeration process, in which incipient fusion of the iron ore fines takes place in the presence of flux and solid fuel. The product of the process will be a hard, porous and lumpy mass. Sinter is a porous and lumpy mass of Iron Oxides in Agglomeration process. Sinter plants agglomerate Iron Ore Fines with addition of flux and solid fuel. Sinter gets partially reduced with the available solid fuel and deficit oxygen. With the addition flux content, softening and melting point comes down and raw flux addition is minimized lowering in the fuel requirement at Blast Furnace as compare to the other Iron bearing materials. Due to the prepared burden, Blast Furnace productivity improves. Sintering is process of agglomeration of ore fines by fusion of ore particles due to combustion heat of solid fuel (coke, coal etc.) present in the mix. Fines generated during mining and beneficiation of iron ores cannot be charged directly into Blast Furnace, the sintering of such fines makes it usable and desirable Blast Furnace feed. Sintering is a heat exchange process. In a static sinter bed there are various zones like; cold sinter, hot sinter, combustion zone, preheating zone, drying zone and cold charge. There is a downward movement of each zone with the forward movement of the pellet throughout the entire length during sintering. Inconsistency of input raw material is avoided by processing required input through Sinter. Consistent Sinter chemistry, physical & high temperature properties helps in smooth Blast Furnace operation Sintering is process of agglomeration of ore fines by fusion of ore particles due to combustion heat of solid fuel (coke, coal etc.) present in the mix. Fines generated during mining and beneficiation of iron ores cannot be charged directly into Blast Furnace, the sintering of such fines makes it usable and desirable Blast Furnace feed. Typical raw material characteristics are given below:

Iron ore fines:-Total Fe-56%, FeO-9%, Fe-10%, SiO2-4.5%, CaO-9%, MgO-2%, Al2O3-2.5%, CaO/SiO2- 2.0

Typical Physical Properties of Sinter are given below:

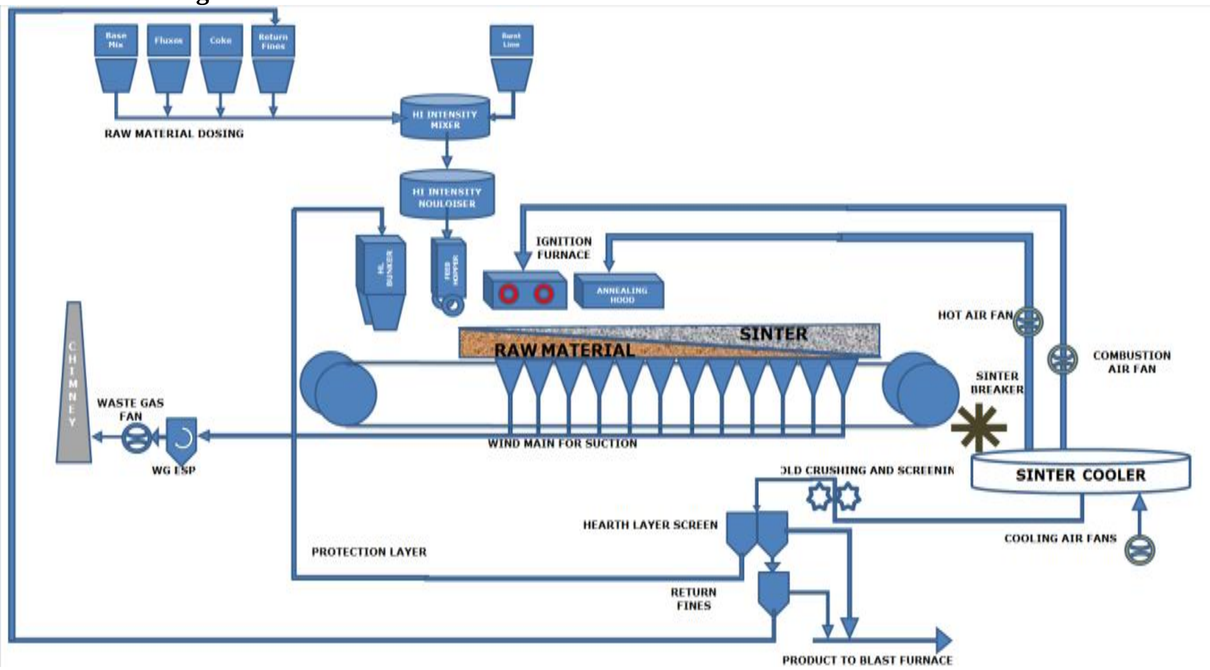
-5 mm< 8.0%, Cum+10-65%, MP-18 mm, Tumbler Index> 75.50, RDI< 25%

BFRF (Blast Furnace Return Fines): Rejection of Fines from Blast Furnace generated after sinter screening at stock house (+5 MM to 40MM) sinter size will be screened at Blast Furnace.<5MM size will be screened out and sent back to sinter through conveyers

<5mm Fraction:-5mm is less than 5mm fraction in sinter product which is not required by the customer (Blast Furnace). -5mm fraction is screened out from sinter in return fines screen before sending to Blast Furnace

Internal Return fines: Internal return fines are fines which are screened at -5mm at Sinter plant and again -5mm used in the sinter making.

Process Flow Diagram



Six Sigma

Six Sigma is a rigorous, focused, and highly effective implementation of proven quality principles and techniques. Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error-free business performance. Sigma is a letter in the Greek alphabet used by statisticians to measure the variability in any process. A company's performance is measured by the sigma level of their business processes. Traditionally companies accepted three or four sigma performance levels as the norm, despite the fact that these processes created between 6,200 and 67,000 problems per million opportunities! The Six Sigma standard of 3.4 problems-per-million opportunities is a response to the increasing expectations.

DMAIC METHODOLOGY

This methodology consists of the following five steps.

Define -->Measure -->Analyze -->Improve -->Control

- Define: Define the problem or project goal that needs to be addressed.
- Measure: Measure the problem and process from which it was produced.
- Analyze: Analyze data and process to determine root cause of defects and opportunities.
- Improve: Improve the process by finding solutions to fix, diminish, and prevent future problems.
- Control: Implement, control, and sustain the improvement solutions to keep the process on the new course

Overview of DMAIC

Project Phase	Six Sigma tools
Define	Project Chatter Voice of customers Tools (surveys, focus groups, letters, comment cards) Process Flow Diagram Project Selection Checklist Critical to Quality and Critical to Process SIPOC Top Down Charting Functional Deployment Process Mapping Value Analysis Quick Wins
Measure	Measurement System Analysis Causes of Sinter Causes effect matrix Cause Analysis Table Cause effect (Fish Bone Diagram) Quality Assurance Matrix

	WHY-WHY Analysis
Analysis	Hypothesis Testing Correlation Scatter plot Regression Simple linear regression Multiple linear regression
Improve	Kaizens
Control	Standard operating procedure Poke-yoke Control Plan PFMEA (Process Failure Mode Effects Analysis)

1) **Define:** The Define phase to clearly define the business problem, goal, statements, level of the project standards, and voice of customer. Define the goals of the improvement activity

a) **Project charter:** Project charter gives overview idea in one single chart the official plan and authorization for the project is summarized in the Six Sigma Project Charter. The Project Charter is a contract between the project team and its sponsor. As such, any changes in the critical elements of scope, objectives, or schedule require approval from the sponsor and consensus of the team.

Project Title: Six Sigma–DMAIC Approach for Improving Quality of Sinter at Sinter plant				
Business Case:				Opportunity statement:
This project results in reduction of sinter cost by reducing rejections at Blast Furnaces. Rejections of Sinter is reduced by improving Sinter quality				Tumbler index sinter is 75.2 against plan of 75.5 %
Goal Statement				Project Scope
Metric	Current level	Target	Target date	Process under Improvement: Sinter Plant-3 Starts with: Input Raw Material receiving area at Sinter Plant -3 Ends with: 9.022 Conveyor
%	75.2	75.5	15.01.2019	
Team selection				
Project Guide: Dr. B.Chandra Mohana Reddy M.Tech, Ph.D				
Member: Mr. Akram Basha				

b) **Critical to Quality and Critical to Process**

Critical to Quality: It's to meet the customer requirements and satisfy the customer and also improve the quality parameters.

Critical to Process: It's the process of input parameters this are variables which are critical approaches the like critical to Quality, critical to Delivery, critical to Cost

Voice of Customer	**Customer Issues**	**Current Level**	**Critical to process**
Sinter tumbler index should be greater than 75.50 and <5mm fraction in sinter should be less than 8%	More rejections of sinter at stock house due to higher % of <5mm fraction and degradation SP-3 to BF-3&4	75.2 Average of Tumbler index in Sinter Plant	CaO %i n sinter 11.7 to 11.9 Burn through temperature should be more than 330 Deg C

c) **SIPOC**

SL.NO	**Supplier**	**Input**	**Process**	**Output**	**Customer**
1	RHMS	Base Mix, Flux and core	Storage of Raw Material	Raw Material	Dosing plant
2	Dosing plant	Raw material	Proportioning of raw materials	Raw Material	1.063 conveyor
3	1.063 conveyor Lime Feeding Granulator Pump House	Raw material Calcined Lime Granulator Dust Water Addition	Mixing of raw materials	Mixed Material with moisture	2.004 conveyor

4	2.004 conveyor Pump house	Mixed Material with moisture Water addition	Nodulizing	Green Mix	2.008 Conveyor
5	2.008 Conveyor	Green Mix	Feeding	Green Mix material	Feed Hopper
6	Feed hopper	Green mix material	Sintering	Hot sinter	Cooler
7	Cooler	Hot sinter	Cooling	Sinter <80 degree .C	Hearth layer screen Return fines screen
8	Hearth layer screen Return fines screen	Sinter <80 degree .C Sinter size <10mm	Hearth layer screening Return fines screening	Sinter size >10mm Sinter size from 5 to 10 mm	Blast Furnaces or storage bins

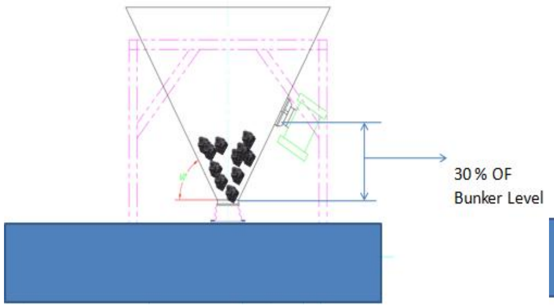
Quick win at Sinter plant:

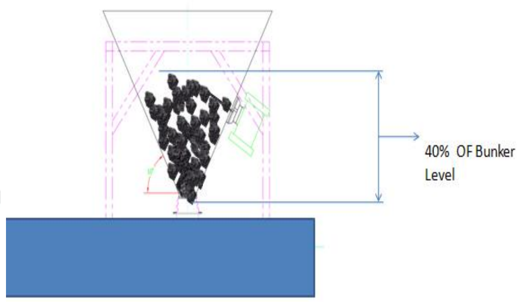
Upon brainstorming, it was identified that following two causes were responsible for the same:

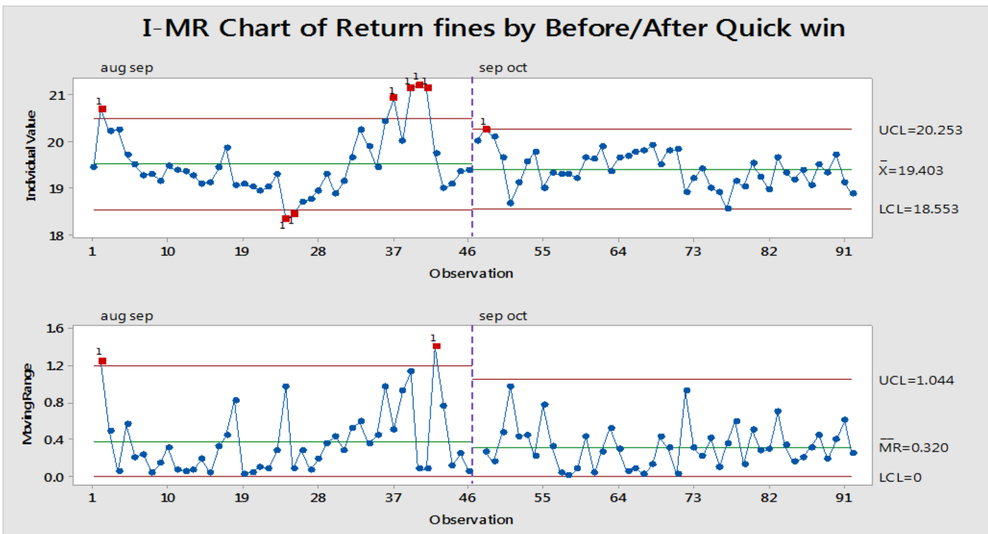
Insufficient Bunker level at Blast Furnace 3 & 4, as the sinter demand was high and there was a demand supply gap.

Increase in <5mm fraction in Blast Furnace Return Fines was mainly during transportation due to height of fall and lower Tumbler Index of Sinter. It is observed in sinter plant, when cooler bunker is empty internal return fines generation is and when cooler bunker is maintained with some sinter the internal return fines generation is less. For avoiding breakage of sinter, Blast Furnace 3 and 4 bunkers was maintained more than 40%. The concept behind this is when sinter is fall directly on the vibrio feeder liners it breaks more, but when sinter falls on sinter it breaks less. The phenomenon can be very well understood by table and diagram

Before Quick Win **After Quick Win**







From Quick win the maintaining of the sinter in blast furnace bunker levels above 40 %, the sinter degradation will decreases and the breaking of sinter from certain height will decreases. < 5 mm of sinter will also decreases.

2) **Measure Phase:** Measure the problem and process from which it was produced, Establish the process baseline to quantify the current operating results as a means of verifying previously-defined business needs, and to properly substantiate improvement results. Evaluate measurement system: to validate the reliability of data for drawing meaningful conclusions.

An argument can be made for asserting that quality begins with measurement. Only when quality is quantified, can meaningful discussion about improvement begin.

Gauge Repeatability and Reproducibility

Conducting Gauge R&R on the Tumbler index at sinter by

- 3 operators
- 10 parts
- 60 Run order

Gauge R&R study:

	Parts 1	Parts 2	Parts 3	Parts 4	Parts 5	Parts 6	Parts 7	Parts 8	Parts 9	Parts 10
operator1	75.569	74.989	73.791	76.001	75.098	75.002	74.995	75.152	75.701	74.872
	75.523	74.981	73.685	76.109	75.101	75.006	74.985	75.136	75.725	74.899
operator 2	75.519	75.002	73.765	75.999	75.109	75.048	74.991	75.122	75.735	74.866
	75.55	75.001	73.798	75.878	75.121	75.016	74.885	75.118	75.752	74.892
operator 3	75.495	75.005	73.662	75.954	75.119	75.031	74.989	75.102	75.693	74.895
	75.597	75.011	73.676	75.849	75.113	75.036	74.929	75.112	75.684	74.878

Two-Way ANOVA Table with Interaction

Source	DF	SS	MS	F	P
Parts	9	19.6574	2.18415	972.091	0.000
Operators	2	0.0059	0.00295	1.314	0.293
Parts * Operators	18	0.0404	0.00225	1.635	0.114
Repeatability	30	0.0412	0.00137		
Total	59	19.7449			

α to remove interaction term = 0.05

Two-Way ANOVA Table without Interaction

Source	DF	SS	MS	F	P
Parts	9	19.6574	2.18415	1283.80	0.000
Operators	2	0.0059	0.00295	1.74	0.187
Repeatability	48	0.0817	0.00170		
Total	59	19.7449			

Gage R&R

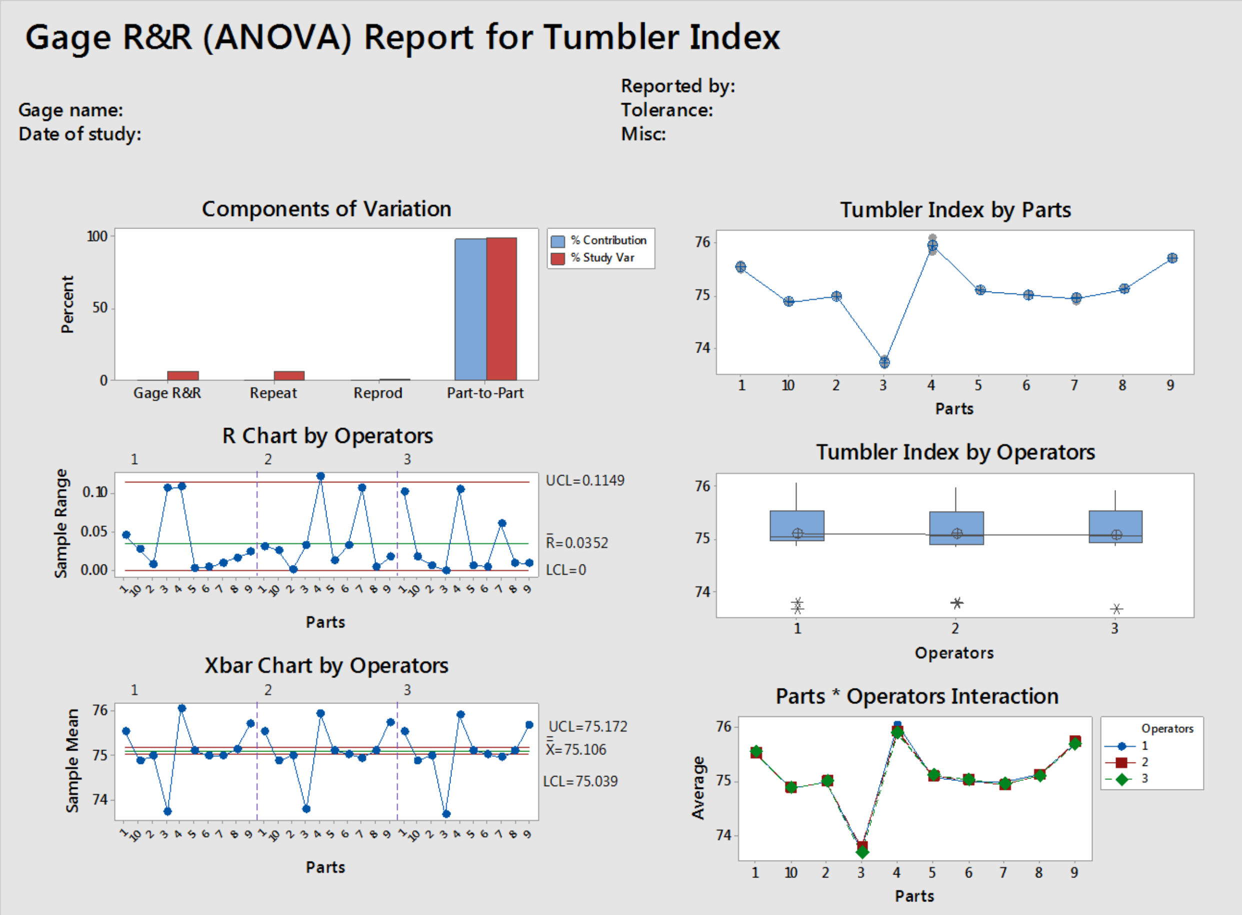
Variance Components

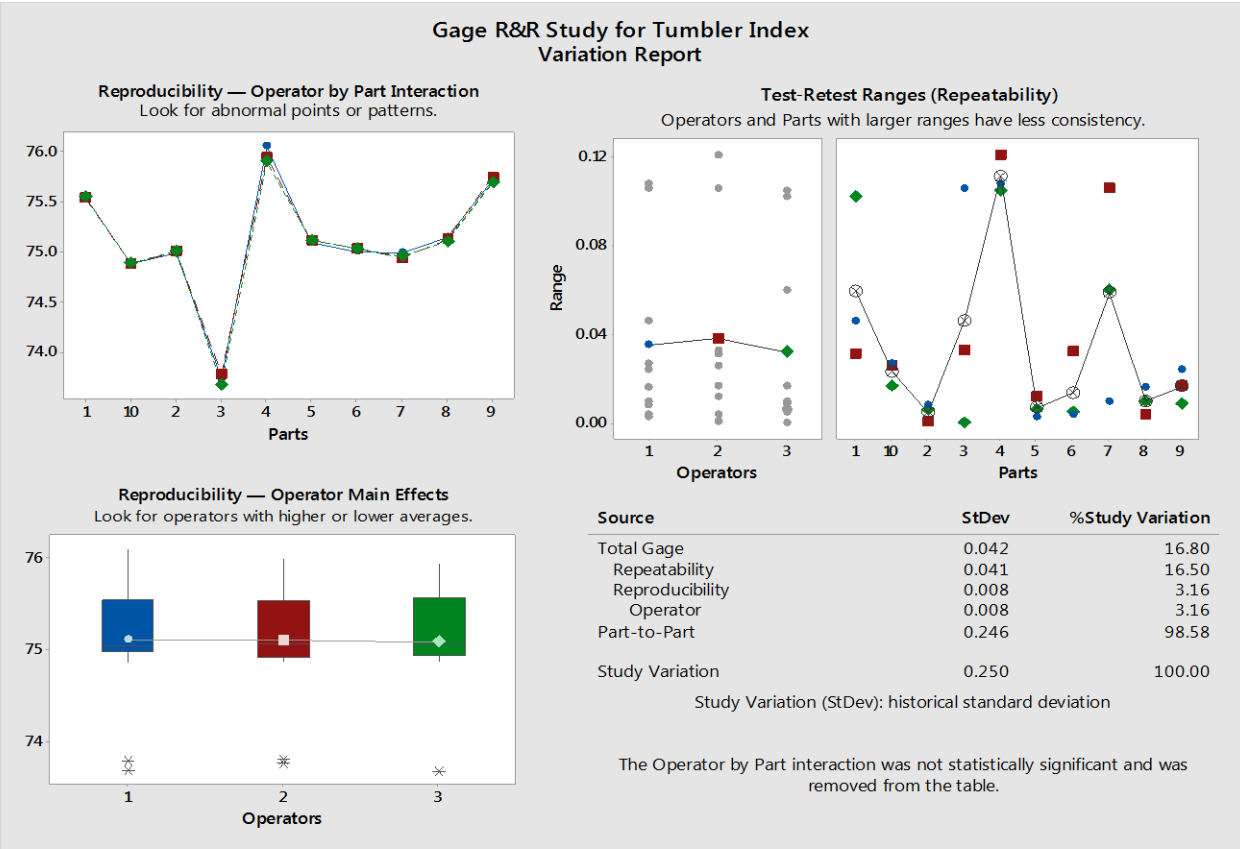
Source	Variance Components	%Contribution (of Variance Components)
Total Gage R&R	0.001764	0.48
Repeatability	0.001701	0.47
Reproducibility	0.000063	0.02
Operators	0.000063	0.02
Part-To-Part	0.363742	99.52
Total Variation	0.365505	100.00

Gage Evaluation

Source	Standard Deviation (SD)	Study Variation (6 × SD)	%Study Variation (%SV)
Total Gage R&R	0.041999	0.25199	6.95
Repeatability	0.041247	0.24748	6.82
Reproducibility	0.007910	0.04746	1.31
Operators	0.007910	0.04746	1.31
Part-To-Part	0.603110	3.61866	99.76
Total Variation	0.604570	3.62742	100.00

Number of Distinct Categories = 20

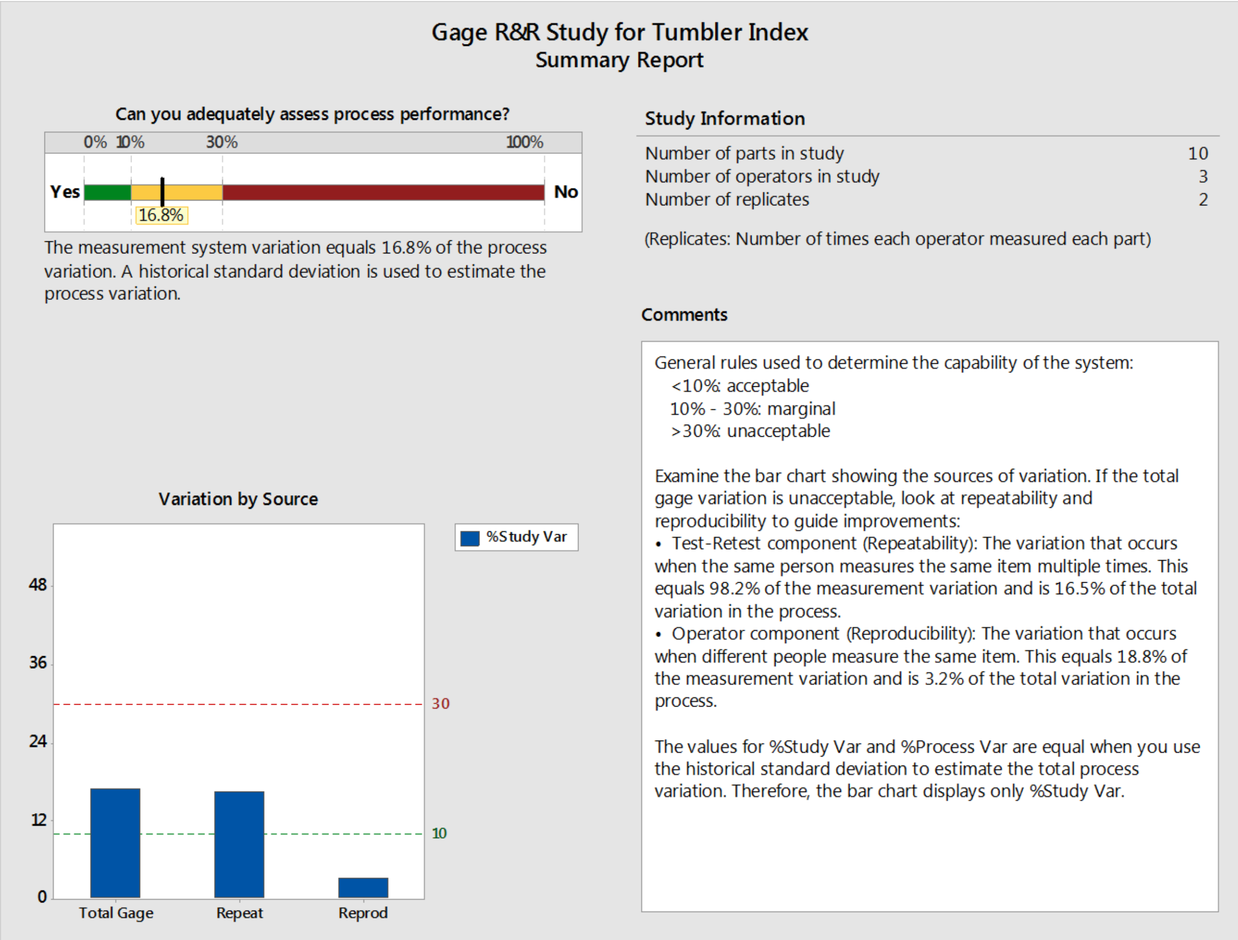




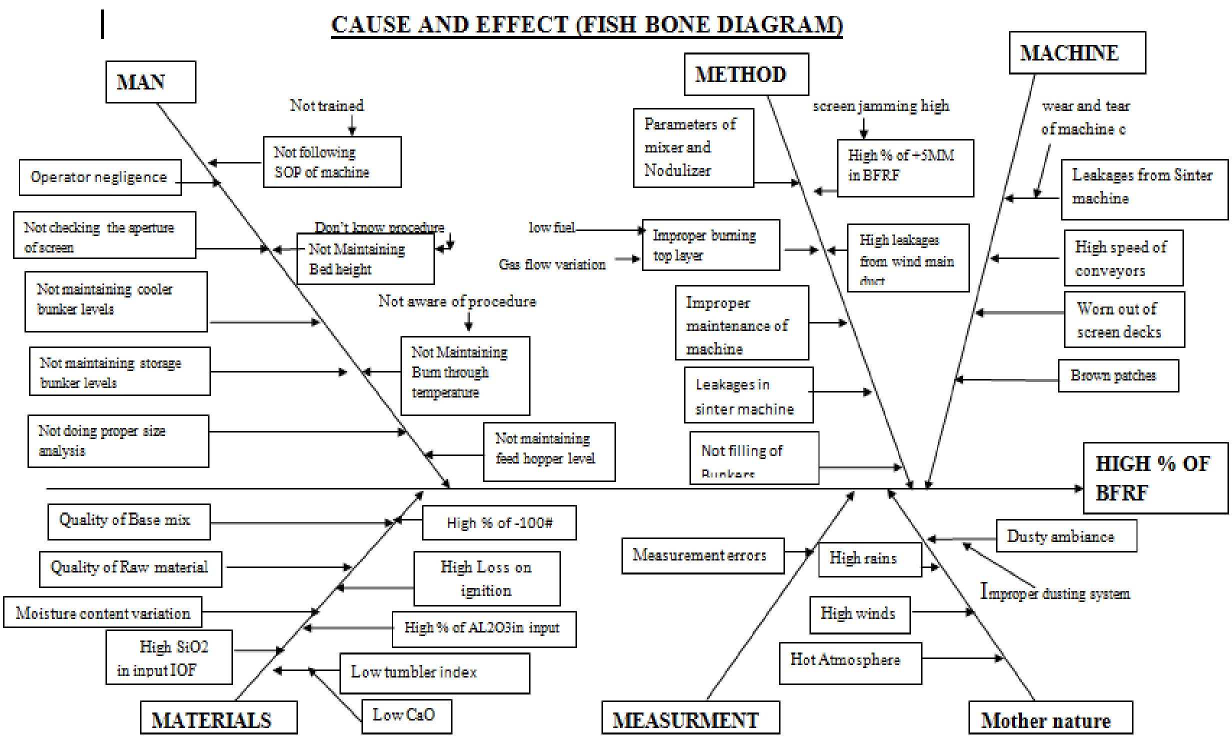
Source	StDev	%Study Variation
Total Gage	0.042	16.80
Repeatability	0.041	16.50
Reproducibility	0.008	3.16
Operator	0.008	3.16
Part-to-Part	0.246	98.58
Study Variation	0.250	100.00

Study Variation (StDev): historical standard deviation

The Operator by Part interaction was not statistically significant and was removed from the table.



Fish Bone Diagram (Cause and effect diagram):

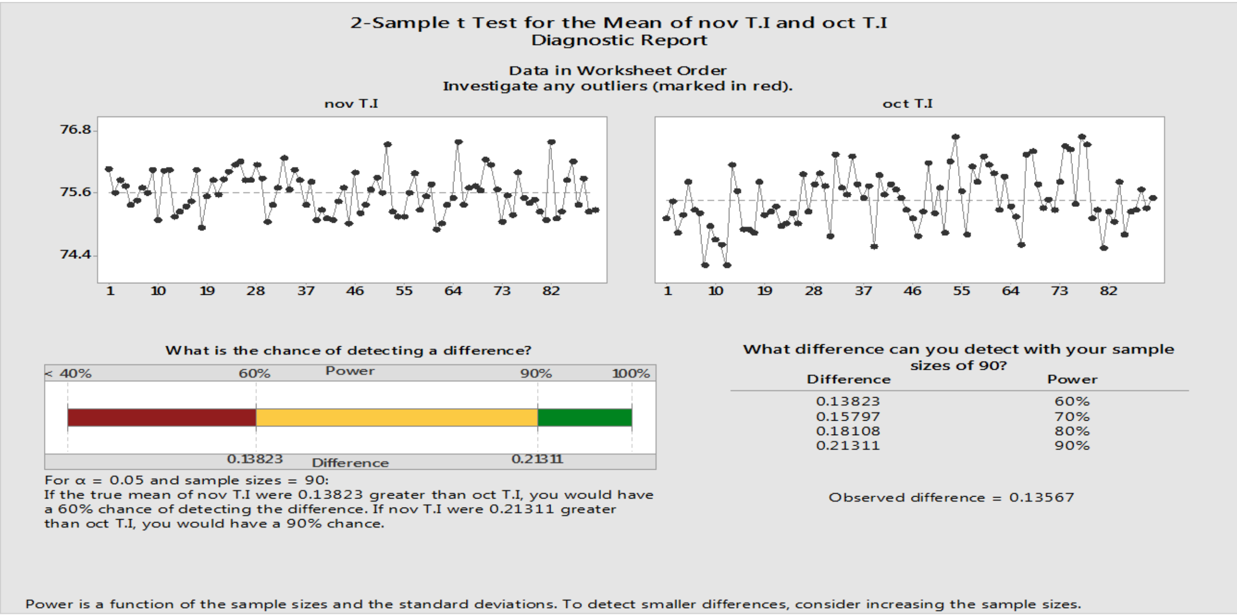


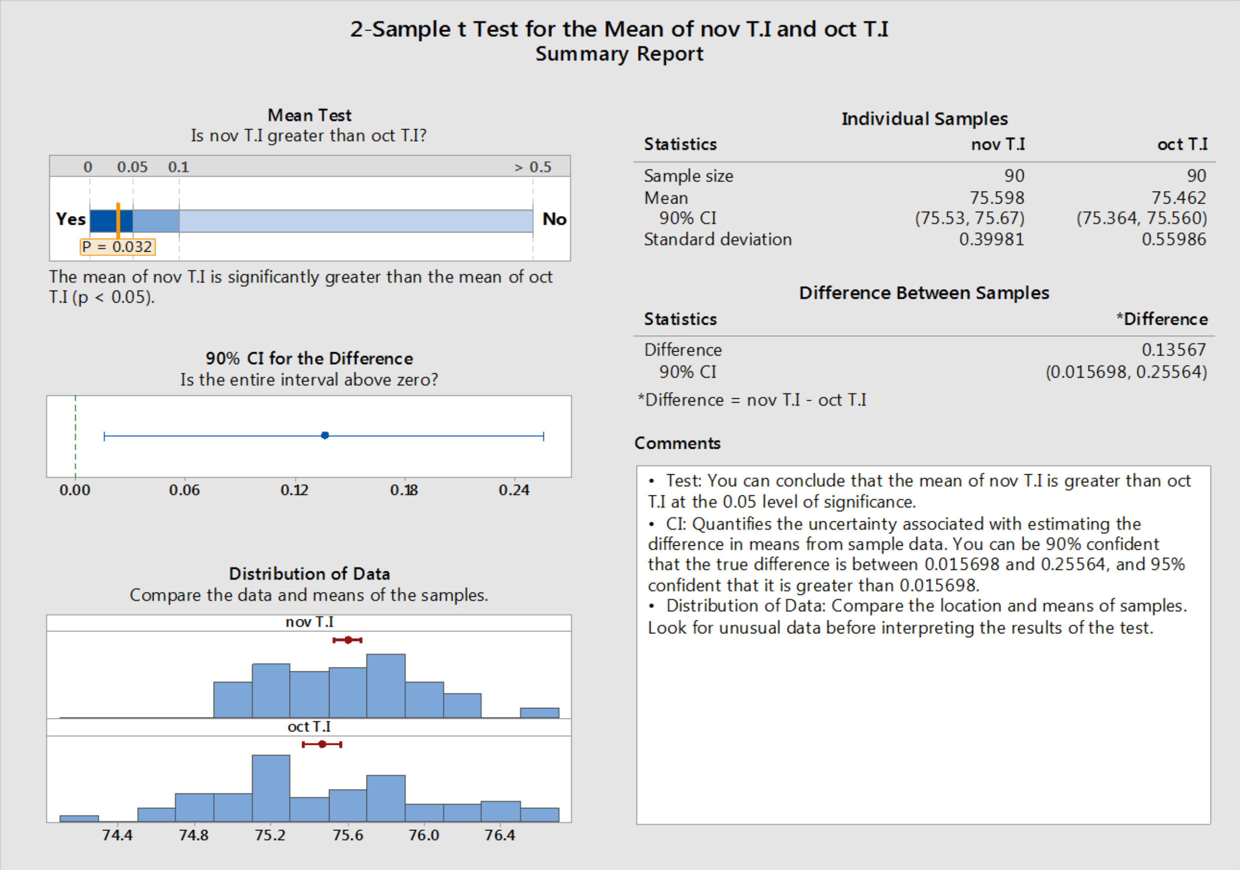
3) **Analyses Phase:** The Analyze deliverable is the choice of the high-level design concept to be created. The design is ‘‘best’’ in the sense that it best meets the Critical to Quality. To accomplish this feat, we must somehow link the Critical to Quality to features of the design.

Hypothesis Testing: The method of testing a hypothesis by comparing it with the null hypothesis. The null hypothesis is only rejected its probability falls below a predetermined significance level, the hypothesis being tested is said to have that level of significance.

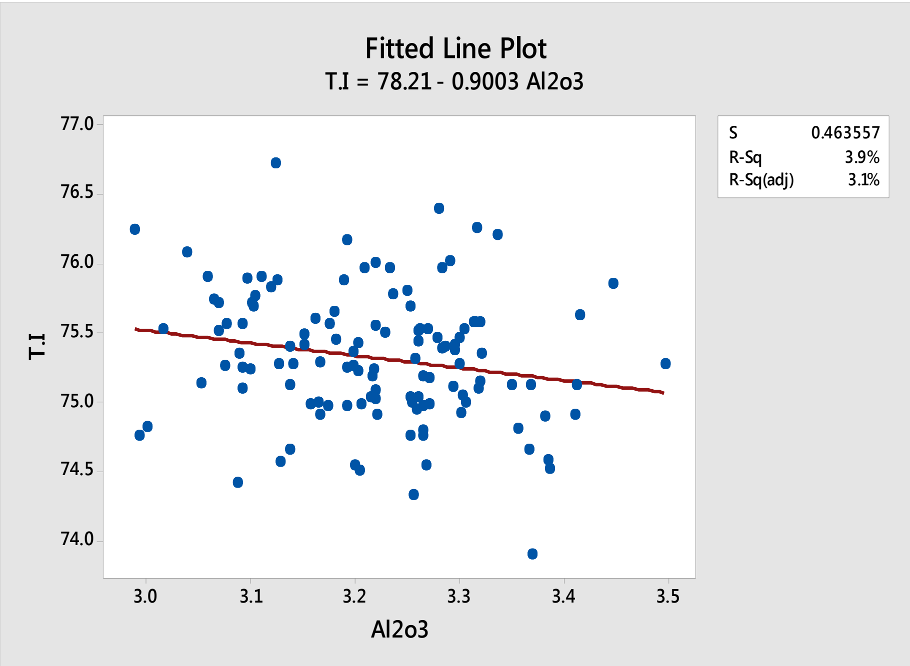
2 Sample T test for the Tumbler index for the month of October and November

October Tumbler index					November Tumbler index				
75.10	75.23	74.57	75.80	76.67	76.05	75.83	76.03	75.13	75.03
75.43	75.33	75.93	76.30	76.53	75.60	75.57	75.83	75.13	75.55
74.83	74.97	75.57	76.13	75.10	75.83	75.85	75.37	75.60	75.17
75.17	75.01	75.57	75.97	75.27	75.73	76.00	75.80	75.97	75.98
75.80	75.21	75.67	75.27	74.53	75.37	76.13	75.07	75.27	75.50
75.27	75.00	75.50	75.90	75.23	75.45	76.20	75.27	75.53	75.40
75.20	75.96	75.27	75.33	75.03	75.70	75.83	75.10	75.77	75.47
75.20	75.23	75.10	75.13	75.80	75.59	75.83	75.07	74.90	75.23
74.97	75.77	74.77	74.60	74.80	76.03	76.13	75.43	75.00	75.07
74.70	75.97	75.23	76.33	75.23	75.07	76.20	75.70	75.37	76.58
74.60	75.73	76.17	76.40	75.27	76.02	75.83	75.00	75.50	75.10
74.20	74.77	75.20	75.77	75.67	76.03	75.83	75.98	76.58	75.23
76.13	76.33	75.70	75.30	75.30	75.13	76.13	75.20	75.37	75.83
75.63	75.70	74.83	75.47	75.50	75.23	75.87	75.36	75.70	76.20
74.90	75.57	76.20	75.27		75.33	75.03	75.67	75.73	
74.90	76.30	76.67	75.80		75.43	75.37	75.89	75.65	
74.83	75.77	75.63	76.50		76.03	75.70	75.60	76.23	
75.80	75.50	74.80	76.43		74.93	76.27	76.52	76.13	
75.17	75.73	76.10	75.38		75.53	75.67	75.23	75.67	

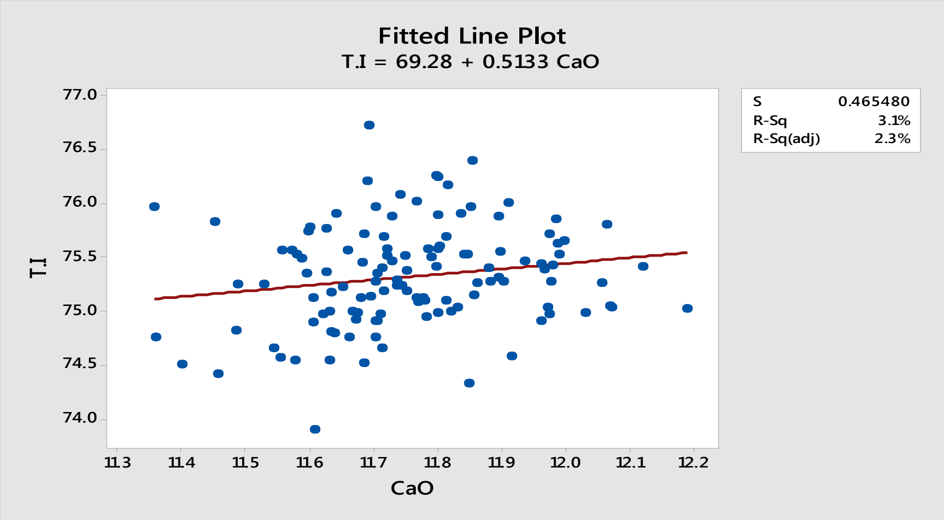




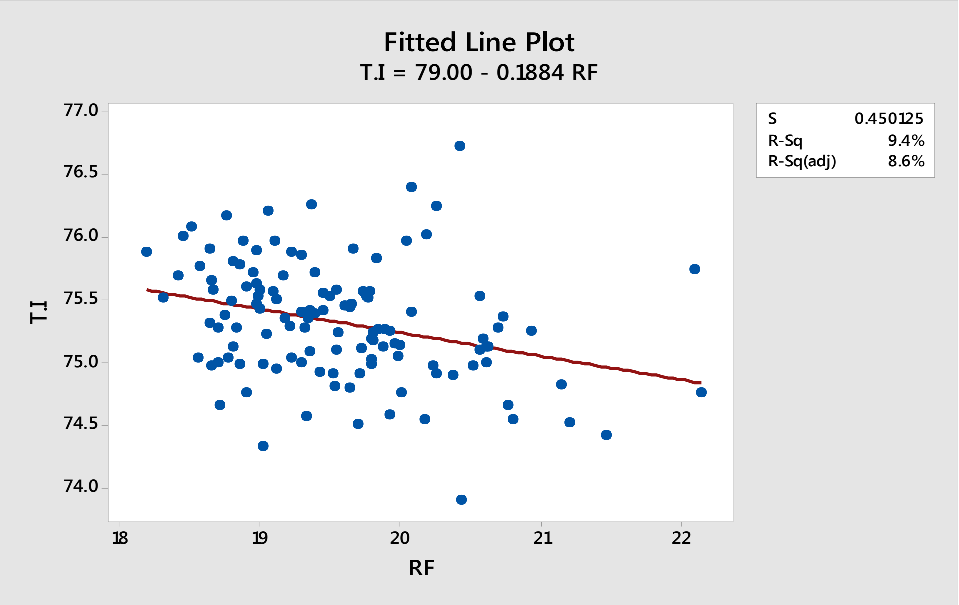
- **Correlation for Tumbler index v/s CaO, Al2O3, Return Fines**



Correlation is negative side which **r value is = -0.10723**
Regression Analysis: Tumbler index versus Al2o3
The regression equation is
T.I = 78.21 - 0.9003 Al2o3



Correlation is positive side which **r value is = 0.151848**
Regression Analysis: Tumbler index versus CaO
The regression equation is
T.I = 69.28 + 0.5133 CaO



From above figure we can conclude that there is negative correlation between Blast Furnace Return Fines and Tumbler index.

Blast Furnace Return Fines Due to the low Tumble index is main effect is causing at Blast Furnace.
Regression Analysis: Tumbler index versus RF
The regression equation is
T.I = 79.00 - 0.1884 RF

4) **Improve Phase:**

The primary objective of the Improve or Design stage of DMAIC/DMADV is to implement the new system. The first consideration is to prioritize the various opportunities, if more than one proposal exists. Once a preferred approach has been determined, the new process or product design is defined and optimal settings. This new design can then be evaluated for risks and potential failure modes.

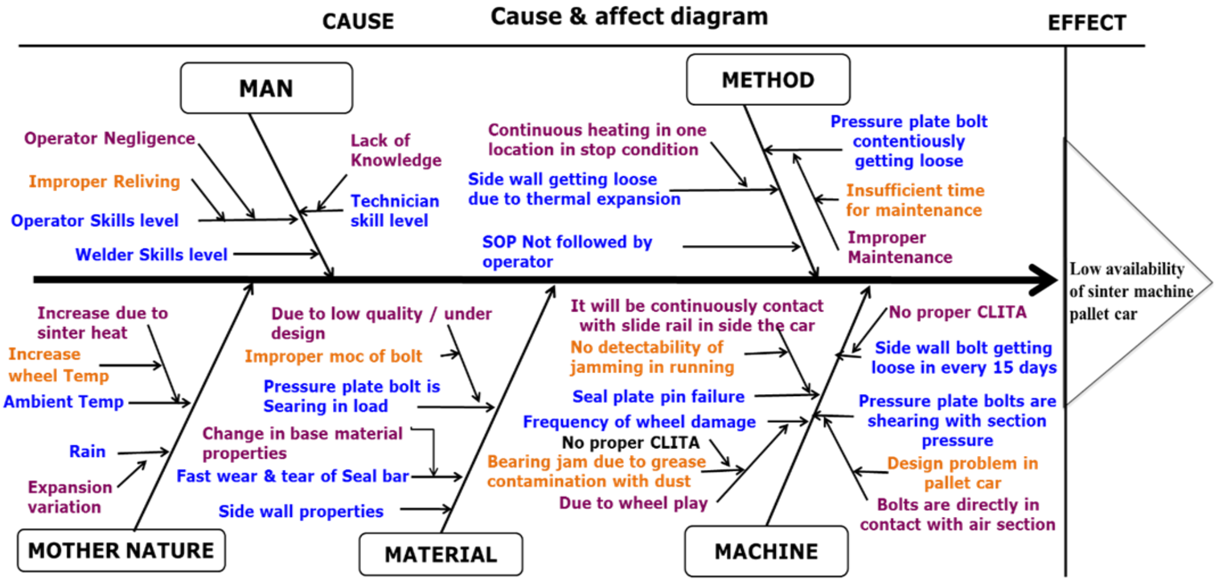
Kaizen:

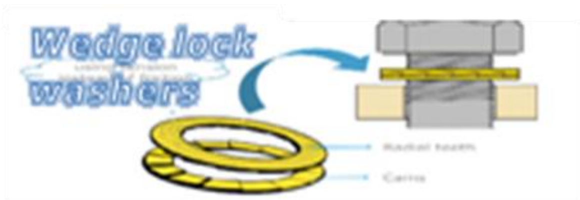
Kaizen is a Japanese word. Kai means Change and zen means good. Small changes system can lead to big improvement in industrial areas. To get effective results and sustain the process the kaizen plays a major role Kaizen can be performed by an individual or group of people (Small Group Activities or Quality Circles)

Kaizen 1: Reducing the frequent loosing of sinter machine upper side wall bolts.
Before (Situation)

Frequently re-tightening of bolts in every 15 days
Because of thermal expansion during frequent stat & stop.

Root Cause Analysis





Improvement Measures

- **Plan:** Planned to introduce wedge lock washers to reduce side wall bolt loosening frequency due to thermal expansion.
- **Do:** Wedge lock washers has been installed in 6 no spare pellet car side Wall & marked with white paint.
- **Check**: We made a check list for inspection. After inspection it has been observed that bolts are not loosening up due to thermal expansion.
- **Act:** Wedge lock washers to be introduced in all side wall bolts minimize the frequency failure of side wall damaged by loosening of bolts

Remarks

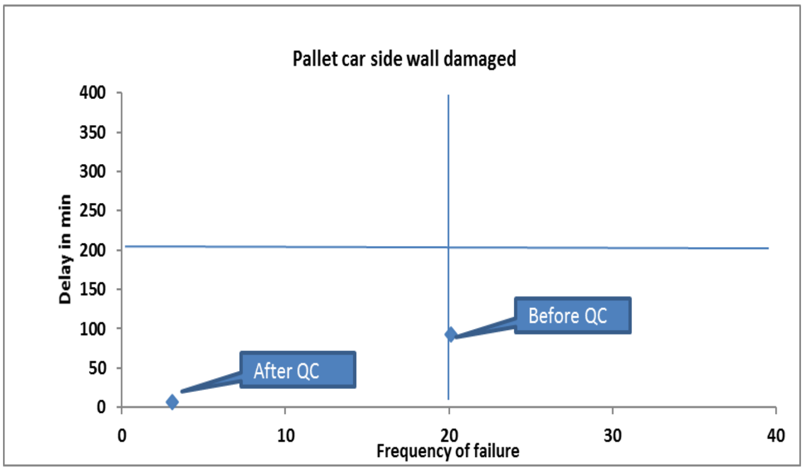
	B Shift	Name: Nandish	Date:16/12/1
Car no	Right side Upper side wall	Left side upper side wall	Remark
115	ok	ok	
93	ok	ok	
135	ok	ok	No loosened
21	ok	ok	found
162	ok	ok	
173	ok	ok	

After (Situation)

After improvement the frequently re-tightening is eliminated.

Benefits:

Frequency of sidewall has eliminated due to bolt loosing & spillage between to side wall has stopped because of loosing of bolts.



After this improvement the impact of the cause has reduced & the cause is shifted from 2nd quadrant to 1st quadrant. By this arrangement we made 100% detachability & MTTR has reduced. Depending on the Play condition of wheel, Pallet car will be positioned for replacement.

KPI Name	Availability	
Improvement	From: 96.5 %	To: 97.5%

Standardization: SOP Revision has made

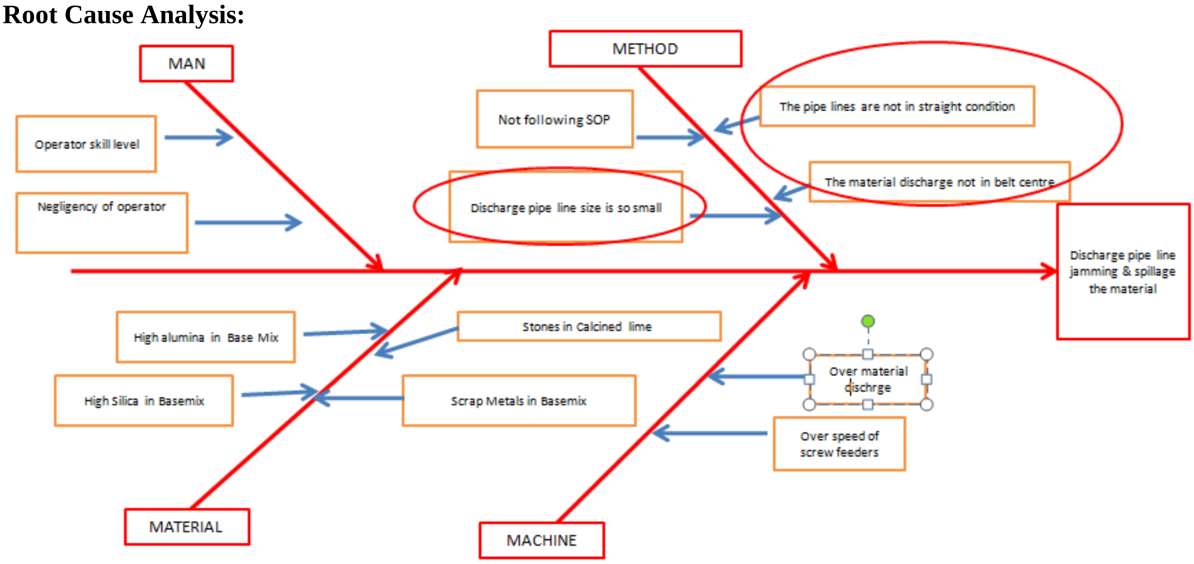
Single Point Lesson: Technology improvement by replacing double nut to single nut with wedge washers

Kaizen 2: E9.021 Discharge Vibrio feeder fixing.

Before (Situation)

E9.022 belt was tripped frequently in overload because of hopper material & warn out rapidly because of sinter fall from height. More overload cause to damage to break down the sinter.

Root Cause Analysis:



By Brainstorming the Root cause analysis has been identified by the Fish bone diagram in this case in the METHOD mode causes the effect of Discharge pipe line jamming & spillage the material.

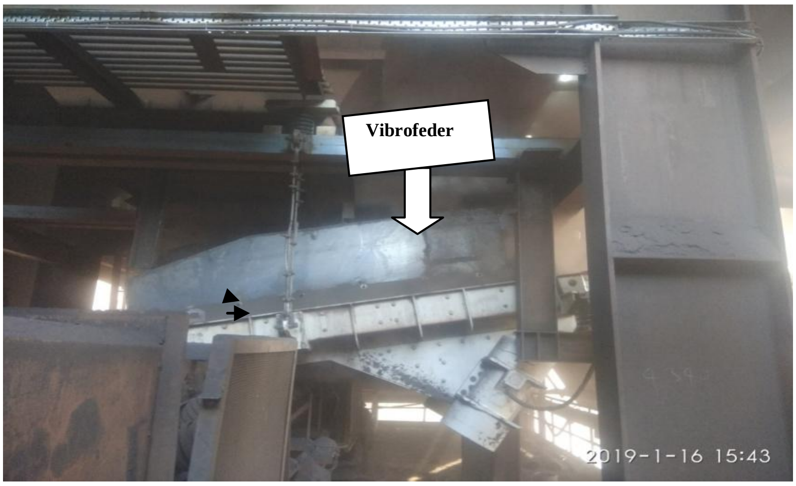
1) The pipe lines are not in straight condition
2) The material discharge not in belt centre
3) Discharge pipe line size is so small

Improvement Measures

By using the Plan-Do-Check-Act

- **Plan**: To avoid the conveyor belt over load.
- **Do**: To install the vibrofeder in between hopper and conveyor.
- **Check:** To check the probability and approach.
- **Act:** To install the vibrofeder and check discharge

After (Situation):



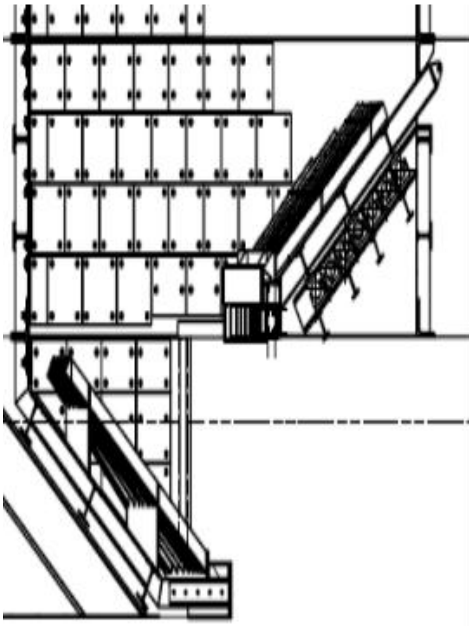
After installing the vibrofeder the overload problem has solved, life span of belt of conveyer will increases

Benefits:

1) To avoid the conveyor overload.
2) To increase the conveyor belt life.
3) To reduce the belts wear out.

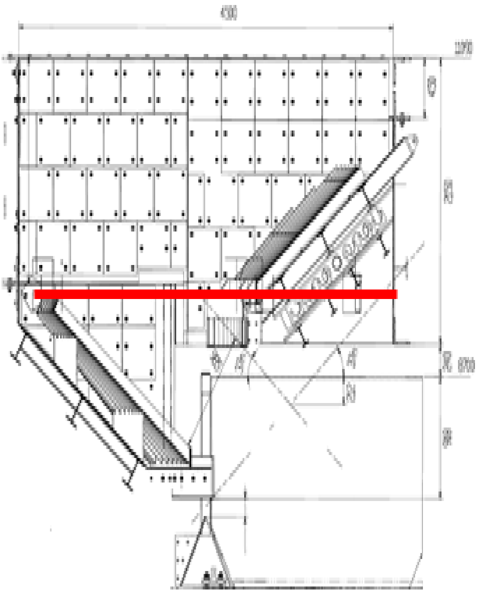
Kaizen 3: Blast Furnace Return Fines reduction by cooler segregation improvement

Before



Before the project the location of the gap between side walls to lower transfer chute is 450 mm. This gap cause the sinter cooling is improper so the sinter degradation increases and < 5 mm increases more

After



After the project the location of the gap between side walls to lower transfer chute is200 mm. Reduce the gap between side walls to lower transfer chute from 450 mm to 200 mm.

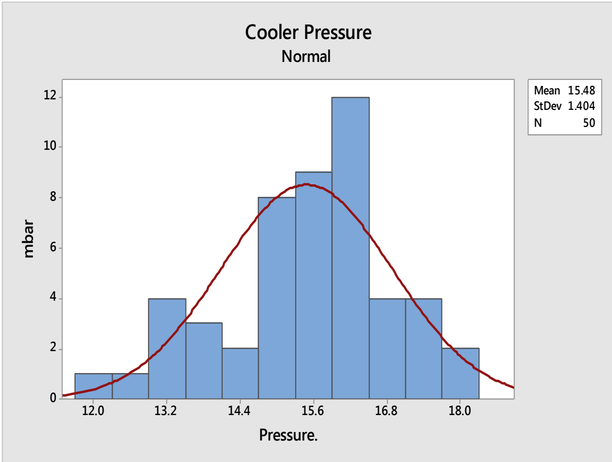
Segregation improved, mean of cooler discharge temperature decreased from 150 to 88 & tunnel pressure slightly increased.

Kaizen 4: Sinter Cooler leakages reduction

A sinter plant takes fine ore and other materials, and fuses them together to produce sintered ore to blast furnaces. A sinter plant can be divided into four parts

1. Raw material mixing system
2. Sinter machine
3. Sinter cooler
4. Sinter screening system

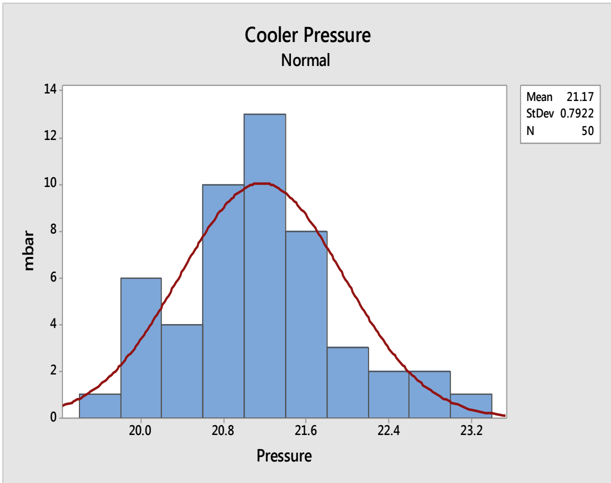
Before



Mean 15.48
StDev 1.404
N 50

The cloth seal at the sinter cooler which is damage for so many times due to sinter pressure and it's so difficult to operator to recover with new cloth seal

After



Mean 21.17
StDev 0.7922
N 50

Instead of cloth seal we use the metallic seal

Tunnel pressure mean was slightly increased from 15.48 to 21.17 mbar, after modification of cloth seal to metallic sea

Control Phase: Implement, control, and sustain the improvement solutions to keep the process on the new course. Contr[illegible] summary of the systems for controlling the variation of all product and process characteristics, important for quality and engineering requirements. It's a contract between the supplier and customer, the entire control strategy for a system, Sub system or component as the basics for development of a process work instruction (SOP), Identify all customer specified characteristics.

- Prototype
- Pre-launch
- Production

Reduce variability, which leads to warranty costs, Increases productivity through Reduce down time, Reduce setup

Fewer repairs, Efficient control, Optimized product costs, Improvement communications within a company, Improvement communications between the organizations, it's a customer and its suppliers

Provides emphasis on production, Provides a focus on process control, Promotes proactive planning, Provides an entire picture of control, Promotes a continual improvement , Improve product quality

Standard operating Procedure (SOP):

For Sinter Quality Control has been revised

Title - Procedure for sintering process control

Objective: - To Achieve maximum productivity of sinter without affecting the quality or Endangering the plant & equipment.

Responsibility: - Shift In-charge (Operations) Area 1 &2, Field operators & Control room operator.

General information: - Sintering process is designed to convert iron ore fines into product suitable for Blast Furnace.

Raw material preparation: - Uniform size and desired quality of Iron ore fines, flux & fuel (- 3 mm of 90%) is an essential aspects of raw material handling system.

1. **Proportioning of raw material in weigh feeders:** - Any deviations in set weights shall upset the sintering process. Hence weigh feeder calibration (once in a three month)/ checks to be done regularly.
2. **Mixing & Nodulizing**: - Addition of moisture plays an important role in the process. Moisture for good sintering process should be optimum. It can be more or less. Approximately 7 -8 % moisture of total mix is desired in normal case & normal weather.
3. **Feeding & segregation of raw mix onto sinter machine**: -By varying the feed drum speed with respect to sinter machine speed, green mix is fed to the sintering strand.
4. **Ignition below the furnace: -** Furnace temperature is controlled by maintaining desired gas & air ratios depending on the Calorific value of the gas used.
5. **Permeability of sinter mix on the bed:** - It depends on mix charging to machine, segregation of mix, Moisture in the mix etc.
6. **Cooling of sinter and handling: -** Cooling, crushing and screening the sinter to get the desired size for Blast Furnace usage.

Procedure: -

1. Control room operator in consultation with the shift in charge sets the desired quality of raw material in weigh feeders and moisture requirements in mixing & Nodulizing drum.
2. Weigh feeder and MND operators must check regularly the desired quality of raw material & moisture in the mix is going to the machine.
3. Sinter machine operator must monitor feeding of hearth layer & raw mix on the strand.
4. Sinter machine operator must also monitor the discharge of the sinter at machine discharge end & communicate the same to control room regularly & continuously.
5. 18mtr operator should monitor (with the help of control room operators for temperature reading provided in DCS) the discharge temperature of the sinter at cooler discharge & communicate the same to control room regularly & continuously.
6. Based on the feedbacks given by above mentioned operators control room operator shall increase/ decrease waste gas fan rpm to maintain the optimum machine speed?
7. Control room operator must continuously monitor the burn-through temperature and temperature profile & pressure of wind boxes of the sinter machine. He must also monitor waste gas fan speed / current, ESP inlet temperature / Pressure & ESP field operation and evacuation.
8. After the long shutdowns, sinter machine should be started at lower speed & gradually can increase the speed of the machine based on the conditions available (Temperature / pressure).
9. During running of the machine, control room operator must record and monitor chemical & physical analysis of sinter and other raw materials received from laboratory.
10. Corrective actions, if required, must be taken based on the desired analysis & the gap thereof.

Control room operator should monitor the generation of internal return fine continuously. This gives the indication of the process set in.

Normally FeO, basicity & MgO in Sinter chemistry is monitored. In Blast Furnace requirement is as below and it may vary also depending upon sinter burden in Blast Furnace.

FeO: - 9 – 10%, Basicity: - 2.1 – 2.3 & MgO: - 2.2 – 2.5.

These parameters are maintained as per the customer's need & hence subject to change on demand.

1. To maintain FeO, following are to be checked.
2. Check the coke weigh feeder feeding in weigh feeder.
3. Check the size and quality of the coke breeze (FC>80%).
4. Check moisture in sinter mix (7.2% +-0.5)

5. For any changes in material mix, changes in Solid fuel set point are required.
6. Observe physical appearance of Sinter discharge and Sinter in cooler for corrective action on Solid fuel set point percentage in material mix.
7. Any correction is done to rectify FeO deviation, process has to be observed with an instantaneous sample analysis before making any further correction.
8. For deviation in Basicity and MgO of sinter following are to be checked.
9. Check flux feeders, BFRF feeders, IRF feeders, Calcined lime feeders and Iron ore feeder.
10. Check for Flux size and quality.
11. Check for quality of Internal Return Fines and Blast Furnace Return Fines.
12. Changes in usage of limestone for the usage of Calcined lime.
13. For any deviation of Basicity / MgO, if correction is done process has to be watched for next two consecutive sinter analyses before making any further correction.
14. Iron ore blending percentage can be varied by considering raw material chemistry.
15. To control internal return fines, following should be monitored

Advantages:

1. Improved Blast Furnace productivity & Control, Reduction in coke rate.
2. Minimum addition of trimming additions like limestone / dolomite is required.
3. For getting the good quality & quantity product, sintering process is optimized by varying bed depth, selecting right return fines & fuel rates. Apart from this sintering process is governed by Sinter Machine speed and continuous running of the strand.
4. For maintaining the desired rate of production at desired speed, following need to be monitored & controlled continuously.

To Maintain tumbler index >75% at sinter plant

- Maintain FeO 9-10%
- Maintain uniform sinter bed
- Maintain feed hopper 55-65%
- Maintain cooler bunker >40%
- Maintain screen aperture size
- Maintain bed height >700 mm

To control Blast Furnace return fines followings should be monitored

- Maintain tumbler index >75%
- Maintain FeO 9-10%
- Maintain uniform sinter bed
- Maintain feed hopper 55-65%
- Maintain cooler bunker >40%
- Maintenance of transfer chute from Sinter plant to Blast furnaces, maintain sinter storage level more than 40%
- Maintain healthy bunker level at both furnace
- Maintain screen aperture size
- Maintain bed height >700 mm
- Maintain Sinter CaO >12.8%

To control RDI followings should be monitored

- MgO in sinter +2%
- FeO in sinter 9-10%
- Record the changes made & monitor the process and analysis.
- Coke corrections beyond the deviations may also be required for the reasons mentioned below.
- Return fines generation increases / decreases. Percentage of addition of micro pellet and carbon slurry.
- Bed change effect.
- Unusual temperature trends at discharge.
- Change in the blend composition.

Metallurgical properties of sinter e.g. RDI. Reducibility Index, Tumbler Index,

Shift in charges must monitor & coordinate all these activities with control room operator & field operators to achieve desired sinter machine speed for maximum output. Make use of online analyzer for the prediction of right sinter chemistry. Immediate action can be taken like change in SiO_2, Al_2O_3, MnO, MgO and CaO.

SOP changes reasons

To maintain FeO

Previous - Any correction is done, process has to be observed for next two consecutive sinter analyses before making any further correction.

Revised - Any correction is done to rectify FeO deviation, process has to be observed with an instantaneous sample analysis before making any further correction

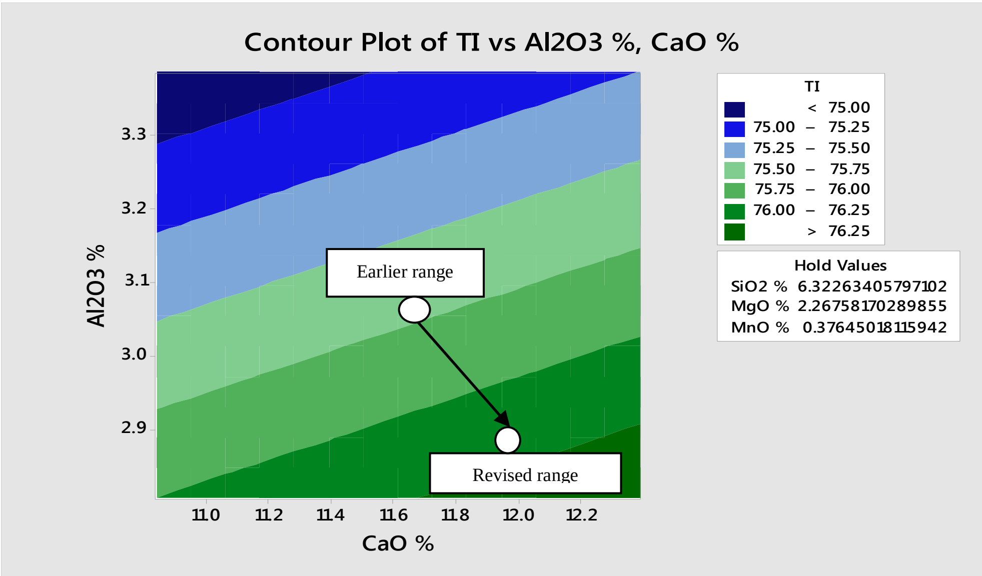
To control Blast Furnace, return fines followings should be monitored

Previous -

- Maintain Tumbler Index >75%
- Maintain FeO 9-10%
- Maintain uniform sinter bed
- Maintain feed hopper 55-65%
- Maintain cooler bunker >30%
- Maintenance of transfer chute from SP-3 to both furnaces 3 & 4.
- Maintain screen aperture size

Revised -

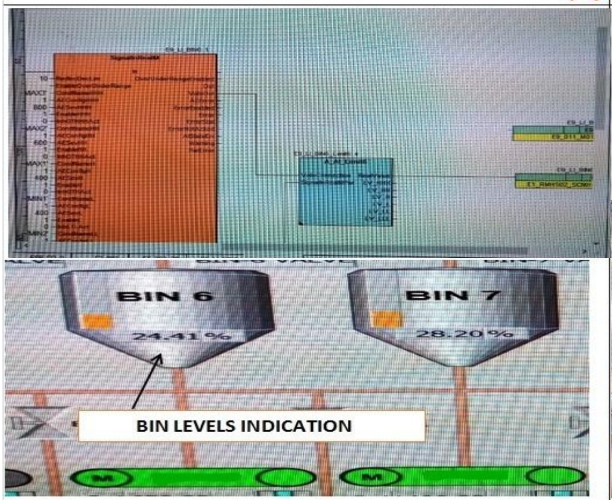
- Maintain tumbler index >75.5%
- Maintain FeO 9-10%
- Maintain uniform sinter bed
- Maintain feed hopper 55-65%
- Maintain cooler bunker >40%
- Maintenance of transfer chute from SP-3 to both furnaces.
- Maintain healthy bunker level at both furnace
- Maintain bed height from 710 to 720 mm
- Maintain Sinter CaO from 11.7 to 11.9
- Maintain Alumina input ore < 3.1%
- New operating ranges for CaO and Al2o3 have been decided with the help of contour plot shown below.

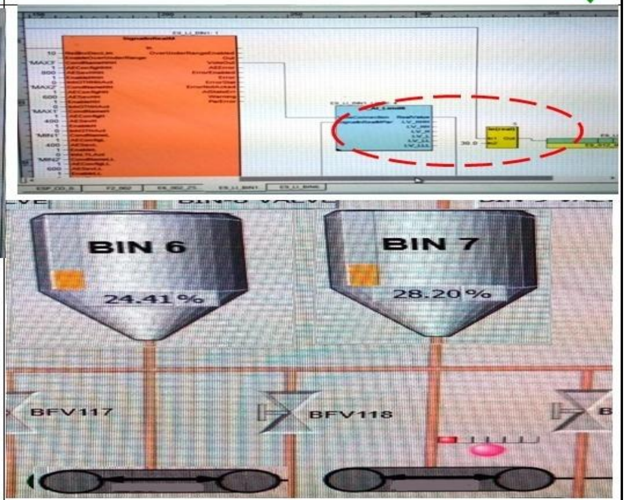


POKE-YOKE for Controlling the Bunker levels

Logic made in Control room in such a way that, if bin level is less than or equal to 40%, then its corresponding belt feeder will not start, so that bin level can be maintained

POKA YOKE		DEPARTMENT: SINTER PLANT 3		AREA:		DATE: 16.1.19
Process:	STORAGE BINS	Equipment:	COOLER	FUNCTION	Shutdown	☐
Objective:	Safety ☐ Human Error Proofing ✔	STATE	Prediction ☐		Control	✔
Description of Problem	Storage bins getting emptied without maintaining minimum bin levels. So sinter fines were being generated.		Detection ✔		Warning	☐
Before Improvement ✘		After Improvement ✔				





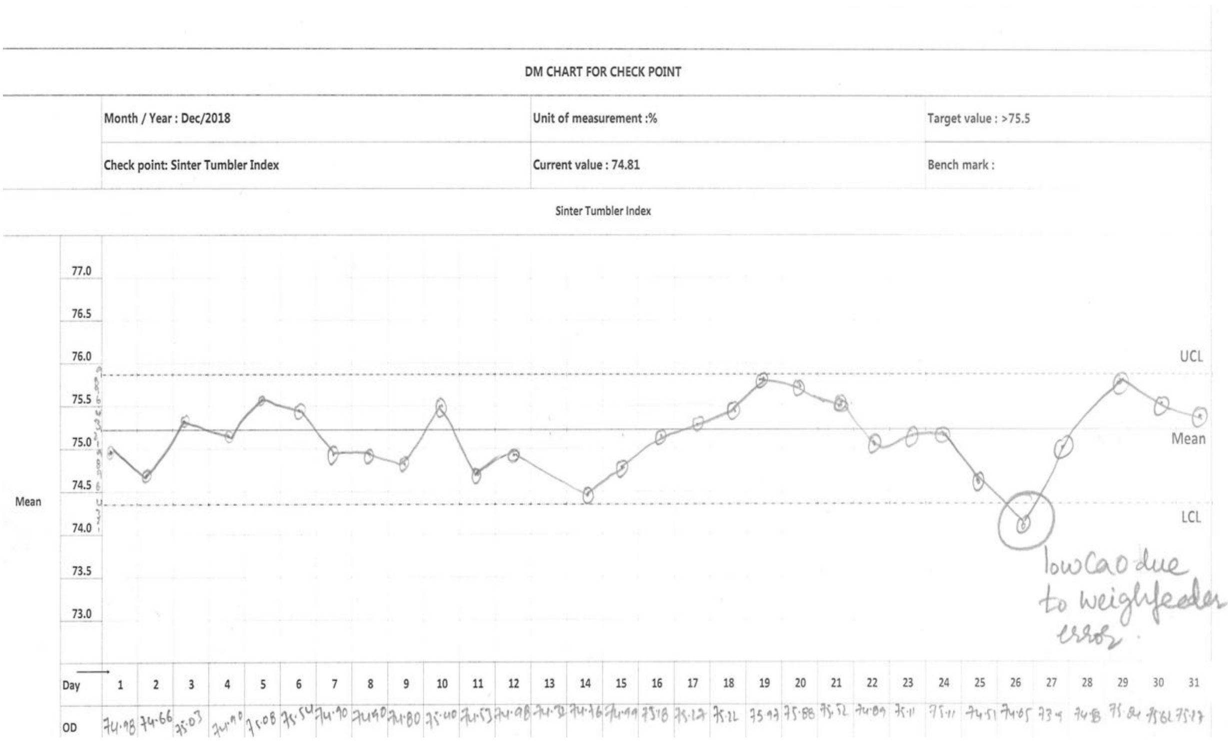
Inference: Logic made in DCS in such a way that, if Bin level is less than or equal to 30%. Then its corresponding belt feeder will not start, so that bin level can be maintained.

Result: Storage bunker levels are maintained above 40%. A snapshot is shown below

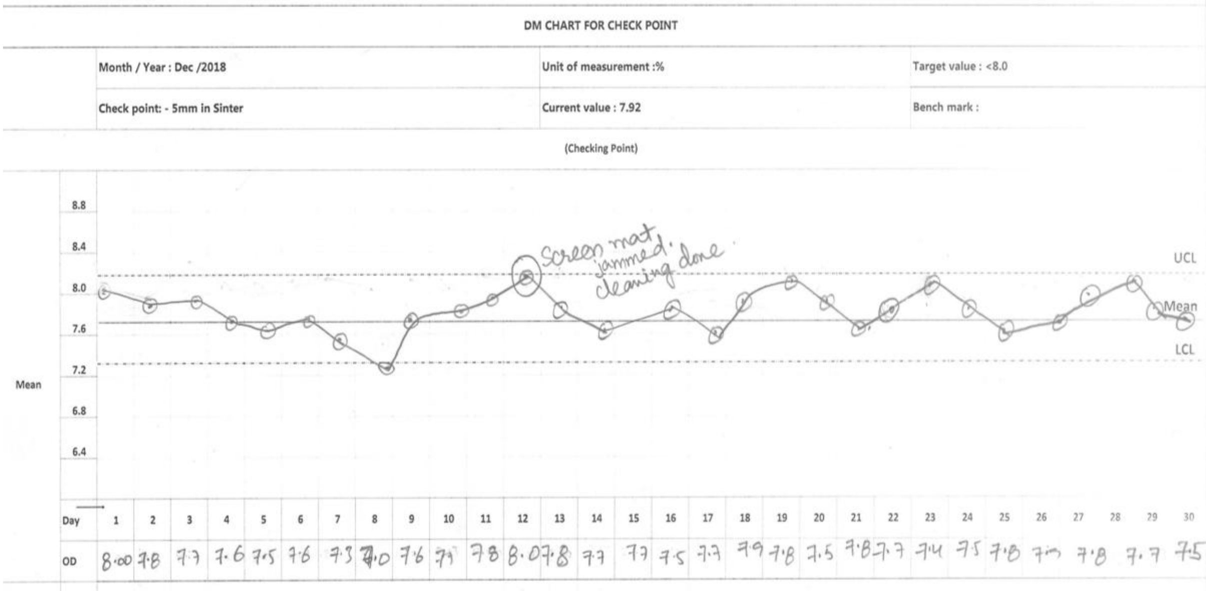
II. RESULTS

To Sustain the Quality parametrs following key performance indices are sustaining on the daily management basics

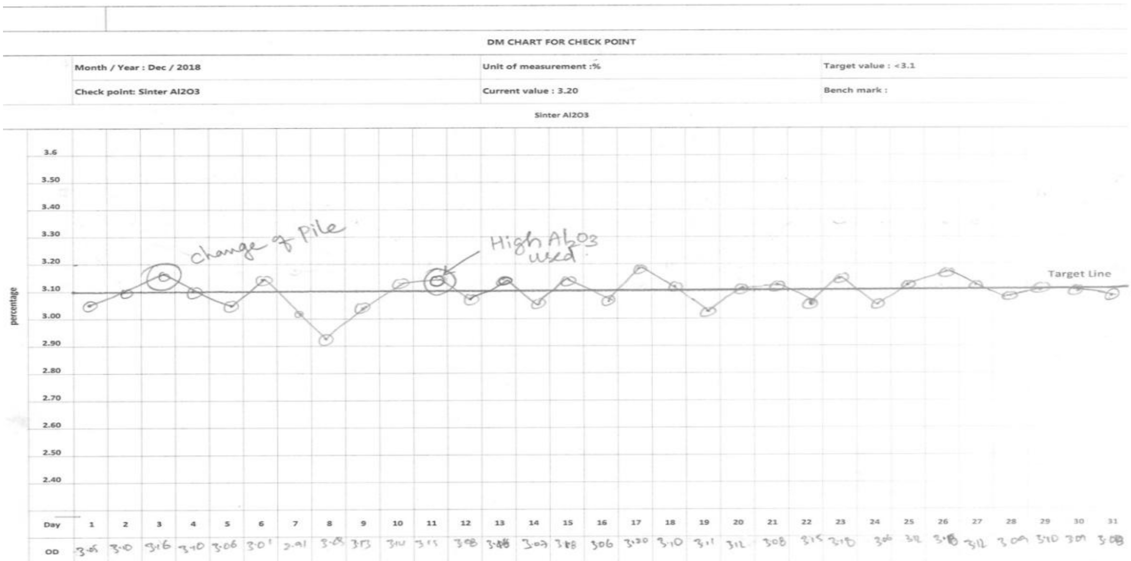
Tumbler index



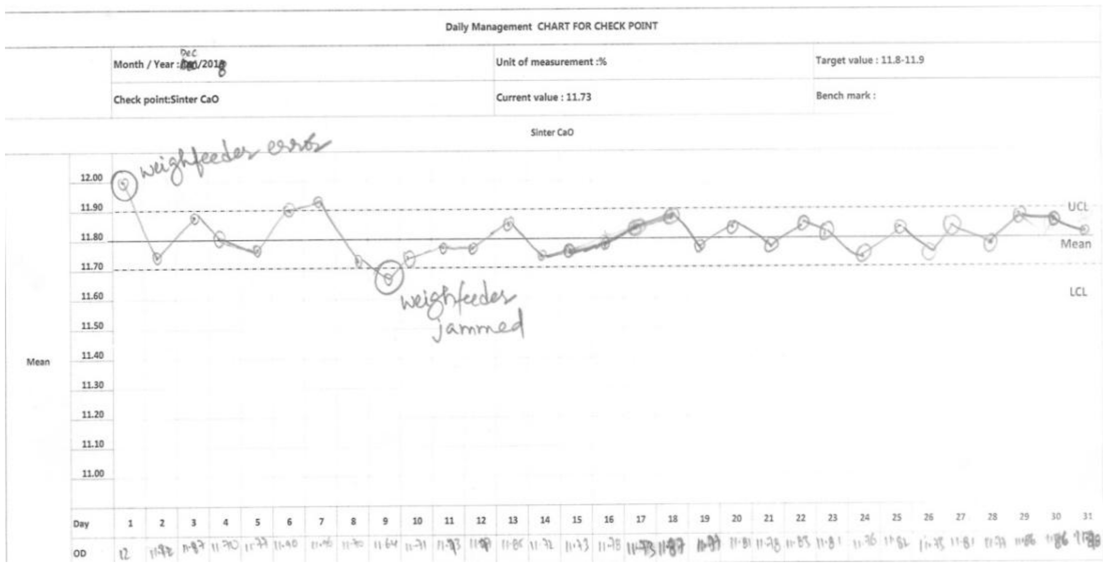
< 5 mm fraction in sinter



Sinter Al2O3

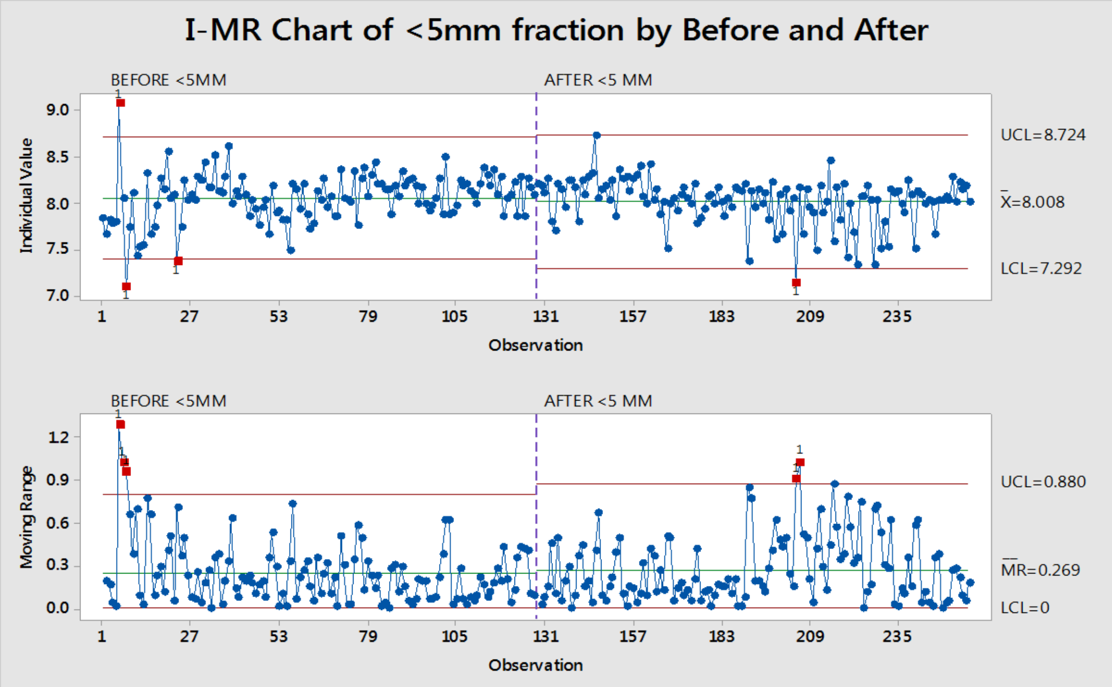


Sinter CaO

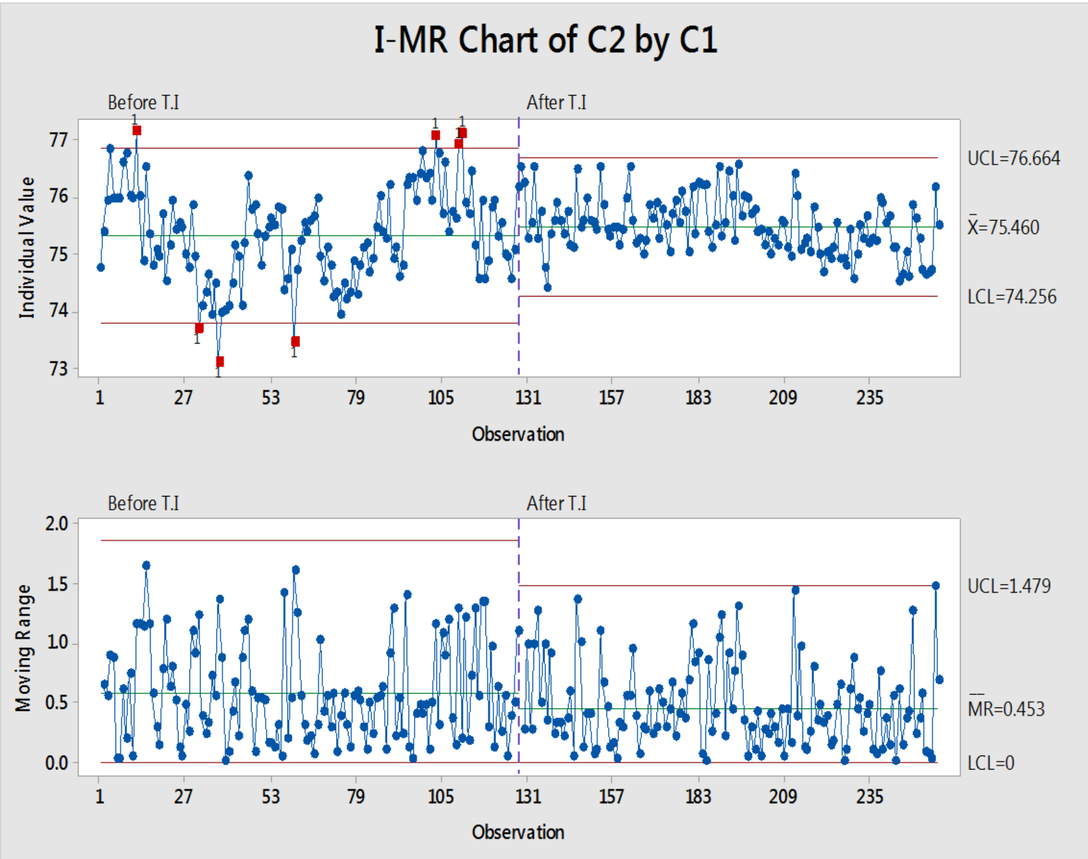


Results before the project and after the project has been shown below

< 5mm of sinter before and after project



Tumbler index of sinter before and after project



III. CONCLUSION

Sinter deterioration is function of Sinter strength (Tumbler Index) and <5mm fraction in Sinter product and external conditions like Al2O3 in Iron Ore Fines. Sinter is subjected to height of fall in bunkers and transfer points of conveyors. Through this project, Tumbler Index, height of fall and <5mm fraction problems were addressed as we have limited control on input ore fines quality.

1. The deterioration by height of fall at Sinter storage bunkers addressed
2. Minimum level of storage in bunkers is increased from 35% to 40%.
3. Discharge chute has been replaced with Vibrio feeder which will reduce degradation of Sinter in chutes. Checklists have been developed for maintaining the health of conveyor transfer points.
4. The Tumbler Index, CaO level in Sinter has been increased from 11.7 to 11.9 %.
5. For increasing screening efficiency, return fines screen mats are being cleaned once in a week. Also, to increase availability of screens, Preventive Maintenance jobs are taken once in 15 days.

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