MIT | School of Distance Education

A

PROJECT REPORT

ON

"Reduce the number of particles that exceed 5 mm in the crushed coal "

UNDERTAKEN AT

Tata Steel Ltd , Kalinganagar

IN PARTIAL FULFILMENT OF

"PGDM-Operation Management"

MIT SCHOOL OF DISTANCE EDUCATION, PUNE.

GUIDED BY

"Mr. Subhakanta Sarangi"
(Head Coal & Coke Operation,Tata Steel Ltd)

SUBMITTED BY

"Soumya Ranjan Pradhan"

STUDENT REGISTRATION NO.: MIT2022C00272

MIT SCHOOL OF DISTANCE EDUCATION PUNE - 411 038

YEAR 2022-24

TATA

Soumya Ranjan Pradhan
Tata Steel Ltd.
Kalinganagar

Dear **Mr Pradhan**,

I am writing to express my sincere appreciation for your hard work and dedication to Tata steel ltd. Your contributions have been invaluable to our team, and I am grateful for all that you do.
Specifically, I want to recognize your outstanding work on
"Reduce the number of particles that exceed 5mm in the crushed coal".

Your leadership and attention to detail have been instrumental in achieving our goals and exceeding our customers' expectations.
Your contributions have not gone unnoticed, and I want to publicly acknowledge your efforts.

I encourage you to keep up the excellent work, and we will continue to support your growth and development within the company.

Once again, thank you for all that you do. You are a valued member of our team, and we appreciate your hard work and dedication.

Best regards,

Subhakanta Sarangi

Head - Operations (Coal, Coke and CDQ)

Tata Steel Ltd.

SUBHAKANTA SARANGI
Head Coal & Coke Operation
Coke Plant, Tata Steel Kalinganagar

DECLARATION

I hereby declare that this project report entitled **“Reduce the number of particles that exceed 5 mm in the crushed coal ”**bonafide record of the project work carried out by me during the academic year **2022-2024**, in fulfillment of the requirements for the award of **“PGDM-Operation Management”** of MIT School of Distance Education.

This work has not been undertaken or submitted elsewhere in connection
with any other academic course.

Sign:- Soumya Ranjan Pradhan

Name:- Soumya Ranjan Pradhan

Student ID: MIT2022C00272

ACKNOWLEDGEMENT

I would like to take this opportunity to express my sincere thanks and gratitude to **"Mr. Subhakanta Sarangi"**, Head Coal & Coke Operation,Tata Steel Ltd, for allowing me to do my project work in your esteemed organization. It has been a great learning and enjoyable experience.

I would like to express my deep sense of gratitude and profound thanks to all Tata Steel Ltd. Kalinganagar staff members of for their kind support and cooperation which helped me in gaining lots of knowledge and experience to do my project work successfully.

At last but not least, I am thankful to my Family and Friends for their moral support, endurance and encouragement during the course of the project.

Sign: Soumya Ranjan Pradhan

Name:- Soumya Ranjan Pradhan

Student ID: MIT2022C00272

ABSTRACT

To make steel in a blast furnace, coal must first be turned into coke. Coke has a dual role in the steelmaking process. First, it provides the heat needed to melt the ore, and second, when it is burnt, it has the effect of 'stealing' the oxygen from the iron ore, leaving only the pure iron behind. In the coking plant, coal is heated in the absence of oxygen to 1250c. This removes any impurities in the coal, resulting in coke, which is a porous substance that is nearly all carbon.

Coking coals are the coals which when heated in the absence of air, first melt, go in the plastic state, swell and resolidify to produce a solid coherent mass called coke. When coking coal is heated in absence of air, a series of physical and chemical changes take place with the evolution of gases and vapours, and the solid residue left behind is called coke.

Conventional cokemaking is done in a coke oven battery of ovens sandwiched between heating walls. They are carbonised at a temperature around 1000o-1100o C upto a certain degree of devolatization to produce metallurgical coke of desired mechanical and thermo-chemical properties.

In coke plant Tata steel kalinganagar around 6000 tons of coal is raised in coal tower after being blended, crushed in 2 stages and moisture being added This eventually will generate a coal cake to be charged in battery Moreover, if there is deviation in grain size distribution of coal, the bulk density of the coal cake will be impacted Greater crushing fineness is related to higher number of particle particle contact points which positively influences cake strength but will decrease bulk density of prepared coal cake

This if not optimized will cause deviation in coke properties and hence impact

iron formation in BF Moreover, these parameters have secondary effects on coal fluidity and on

the degree of pressure exerted to the chamber walls Optimization of crushing fineness and

properties affecting it will maintain the coke properties Continuing to operate with varied

crushing fineness (will result in operational risk of battery

This Project was completed with DMAIC method & approach to Continuous Improvement.

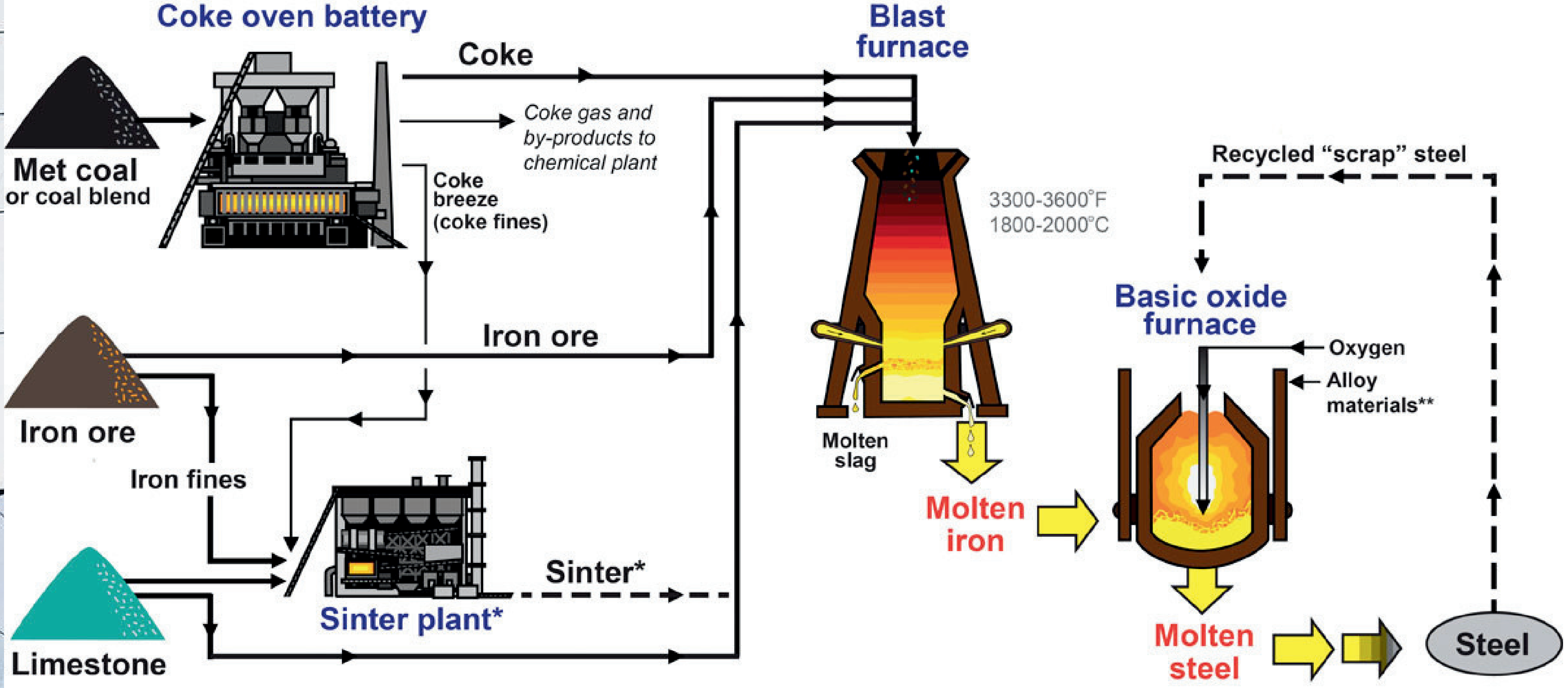
The DMAIC methodology consists of five phases, namely, Define, Measure, Analyze, Improve, and Control.

Soumya Ranjan Pradhan

Date:-5th January 2024

Reduce the number of particles that exceed 5 mm in the crushed coal

Soumya Ranjan Pradhan
Mechanical Engineer,Coke
PLant,Tata Steel Ltd
Kalinganagar


Coke oven battery
Met coal or coal blend
Coke
Coke gas and by-products to chemical plant
Coke breeze (coke fines)
Blast furnace
3300-3600°F
1800-2000°C
Recycled "scrap" steel
Iron ore
Iron ore
Iron fines
Basic oxide furnace
Oxygen
Alloy materials**
Molten slag
Molten iron
Sinter*
Sinter plant*
Limestone
Molten steel
Steel

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D — DEFINE

- Launch Team
- Establish Charter
- Plan Project
- Gather the Voice of the Customer
- Plan for Change

M — MEASURE

- Document the Process
- Collect Baseline data
- Narrow project focus

A — ANALYZE

- Analyze Data
- Identify Root Cause
- Identify and Remove Wastes

I — IMPROVE

- Generate Solutions
- Evaluate Solutions
- Optimize Solutions
- Pilot
- Plan and implement

C — CONTROL

- Control the Process
- Validate project benefits

TABLE OF CONTENTS

“

1. DEFINE

Project Charter ● SIPOC Diagram

Project Charter

Business Case

In coke plant around 6000 tons of coal is raised in coal tower after being blended, crushed in 2 stages and moisture being added. This eventually will generate a coal cake to be charged in battery. Moreover, if there is deviation in grain size distribution of coal, the bulk density of the coal cake will be impacted. Greater crushing fineness is related to higher number of particle-particle contact points which positively influences cake strength but will decrease bulk density of prepared coal cake. This if not optimized will cause deviation in coke properties and hence impact iron formation in BF. Moreover, these parameters have secondary effects on coal fluidity and on the degree of pressure exerted to the chamber walls. Optimization of crushing fineness and properties affecting it will maintain the coke properties. Continuing to operate with varied crushing fineness (lesser) will result in operational risk of battery.

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Problem Statement

The current mean of greater than 5 mm particle size of crushed coal emerging after two stage crushing (Primary & Secondary) is 2.99% with a standard deviation of 0.392 which if increased could affect coal cake formation its bulk density with deteriorated coke properties.

Goal

To identify coal carbonization and equipment running factors responsible for deviation in mean and standard deviation of greater than 5 mm coal crushed particle by optimizing the identified parameters through correlation techniques.

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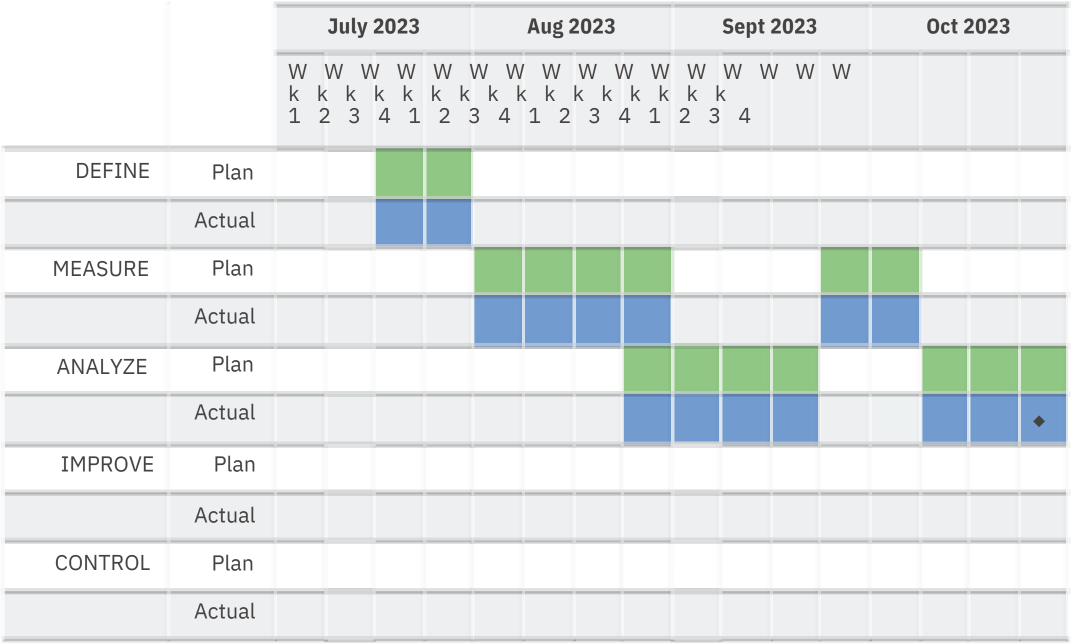
DMAIC Stage : Analyze

Process Impacted : Battery operation

Client Impacted : Battery Operation, Coal Cake Charging in battery

Big Y Impacted : Coke production



Project Status

SIPOC Diagram

BUSINESS MODEL

Key Supplier
Raw Material Management Division, Utilities, Suppliers

Key Inputs
- Coal –
- Battery Moisture

In scope
Coal Blending, Crushingin Primary and Secondary Crushers

Process
Coke plant Operation:
- Carbonization – Formation of Coke

Output
- Wet Coal into coal Tower

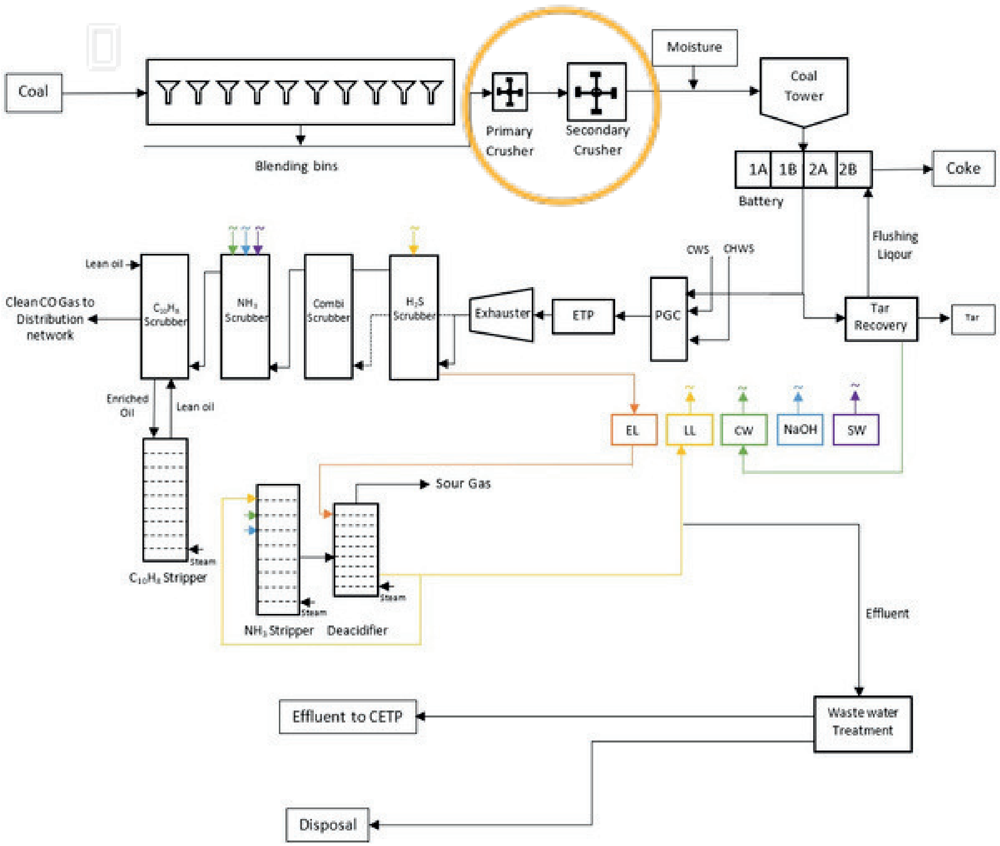
Out of scope
Carbonization in battery,Scrubbers, NH3 Stripping and de-acidifier, PGC, ETP, Naphthalene recovery, Tar Recovery

Customer
- Battery Operation

Deliverables
Crushed coal qualityparameter:

•Greater than 5 mm particle size of crushed coal

Process Flowsheet



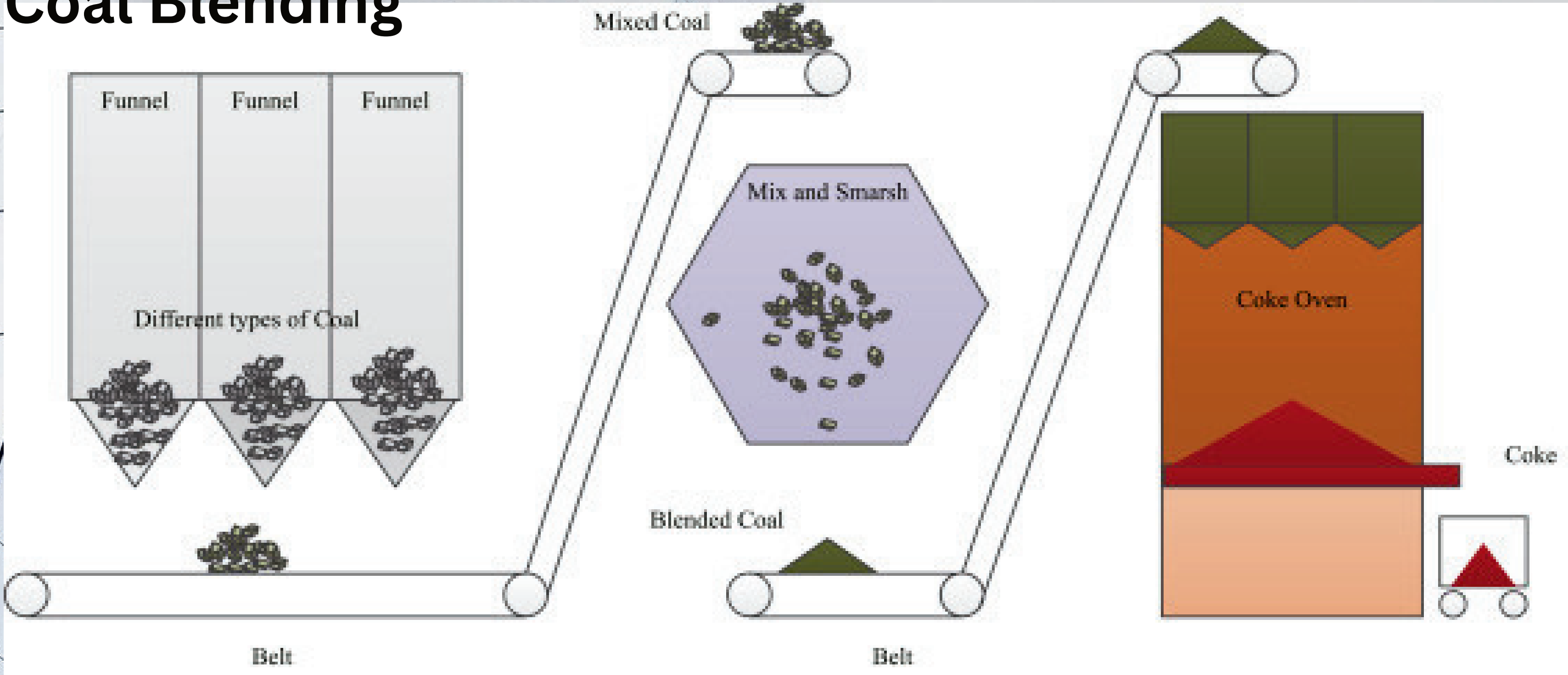
(Battery Operations)

(BPP Operations)

(BOD Operations)

CWS –Cooling water system
CHWS –Chilled Water System
EL –Enriched liquor
LL –Lean Liquor
CW –Coal Water
SW –Stripped Water
CETP –Centralized Effluent Treatment Plant

Coal Blending



Impact Hammer Mill

Research Paper findings

Learning from research papers

Insights from research papers

Paper -1 Effects and impacts of components of coal handling system on coke quality and yield of coke plants [1]

Learning -

- Durithas a significant hardness, because it is quite compact. It is ten times as hard as vitrit.
- The grain size distribution of the coal m M1ix0tu re has a direct influence on the and M40 value of the coke.

Paper -2 Mechanical compaction of coking coals for carbonization in stamp-charging coke oven batteries [2]

Learning -

- Increase in crushing fineness reduces the coal cake density while mechanical strength is improved
- Greater crushing fineness is related to higher number of particle-particle contact points which positively influences cake strength

[1] S. Steinbach, R. Neuwirth, R. Kim, ThyssenKrupp Industrial Solutions AG (TKIS), Germany, “Effects and impacts of components of coal handling system on coke quality and yield of coke plants.” (2015).
[2] Wasielewski,Ryszard&Rejdak,Michał.(2015).Mechanicalcompactionofcokingcoalsforcarbonizationinstamp-chargingcokeovenbatteries.FizykochemiczneProblemyMineralurgii-PhysicochemicalProblemsofMineralProcessing.51.151-161. 10. 5277/ ppm p150114.

Insights from research papers

Paper -2 Mechanical compaction of coking coals for carbonization in stamp-charging coke oven batteries [2]

Learning -

- Increase in crushing fineness reduces the coal cake density while mechanical strength is improved
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  to

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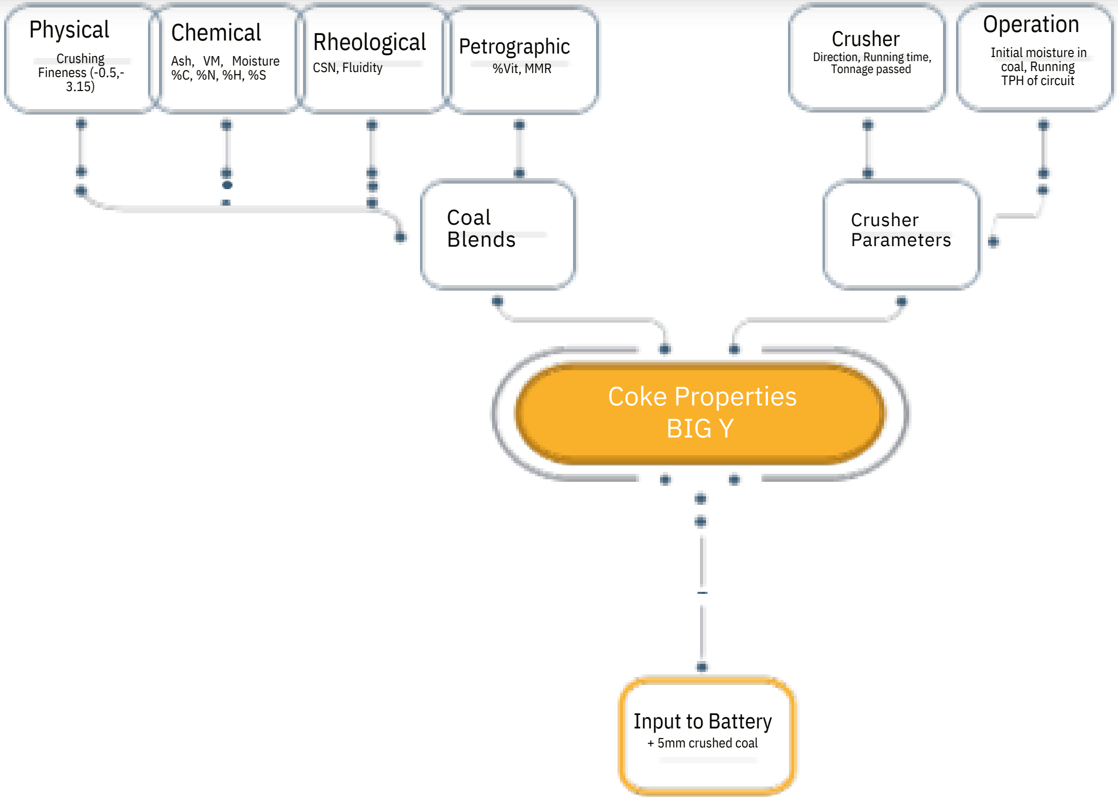
[2] Wasielewski,Ryszard&Rejdak,Michał.(2015).Mechanicalcompactionofcokingcoalsforcarbonizationinstamp-chargingcokeovenbatteries.FizykochemiczneProblemyMineralurgii-PhysicochemicalProblemsofMineralProcessing.51.151-161. 10. 5277/ ppm p150114.

2. MEASURE –For Crushing Fineness

- Exploratory Data Analysis
- Data Distribution
- CTQ drilldown
- Parameter Analysis
- Data Dictionary

CTQ Drill Down



PARAMETER ANALYSIS : Categorization of data

Coal Blending

1.

- Physical properties -Crushing fineness
- Chemical properties-Proximate, Ultimate Analysis
- Petrographic Properties-MMR, Vit%
- Rheological Properties –CSN

Frequency-CSI lab data –shiftwise (3 times a day)

Crusher Parameter

2.

- Running time
- Direction of running
- Tonnage passed through each crusher
- Crusher combination running

Frequency–CSI lab data –shiftwise (3 times a day)

PARAMETER ANALYSIS : Categorization of data

```
df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 276 entries, 0 to 275
Data columns (total 28 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   Date                  276 non-null    datetime64[ns]
 1   Type of Blend         276 non-null    object
 2   VM                    261 non-null    float64
 3   Moisture              263 non-null    float64
 4   Ash                   261 non-null    float64
 5   S                     276 non-null    float64
 6   C                     276 non-null    float64
 7   N                     276 non-null    float64
 8   H                     276 non-null    float64
 9   CSN                   273 non-null    float64
 10  Contraction           276 non-null    int64
 11  Expansion             276 non-null    int64
 12  Max. Fluidity         276 non-null    int64
 13  Vit%                  276 non-null    float64
 14  MMR                   276 non-null    float64
 15  -0.5                  251 non-null    float64
 16  -3.15                 251 non-null    float64
 17  TPH CC 11             276 non-null    int64
 18  Initial Moisture      273 non-null    object
 19  Primary Crusher       276 non-null    int64
 20  Running Time (Min)    276 non-null    int64
 21  Direction             276 non-null    int64
 22  Coal raised           269 non-null    float64
 23  Secondary Crusher     276 non-null    int64
 24  Running Time (Min).1  276 non-null    int64
 25  Direction .1          275 non-null    float64
 26  Coal raised.1         269 non-null    float64
 27  Crushing Fineness     253 non-null    float64
dtypes: datetime64[ns](1), float64(16), int64(9), object(2)
memory usage: 60.5+ KB
```

“

Data set

•

```
df.shape
(276, 28)
```

The first screenshot shows the total number of columns (Features) and rows (data points) in the data set to be 28 and 276

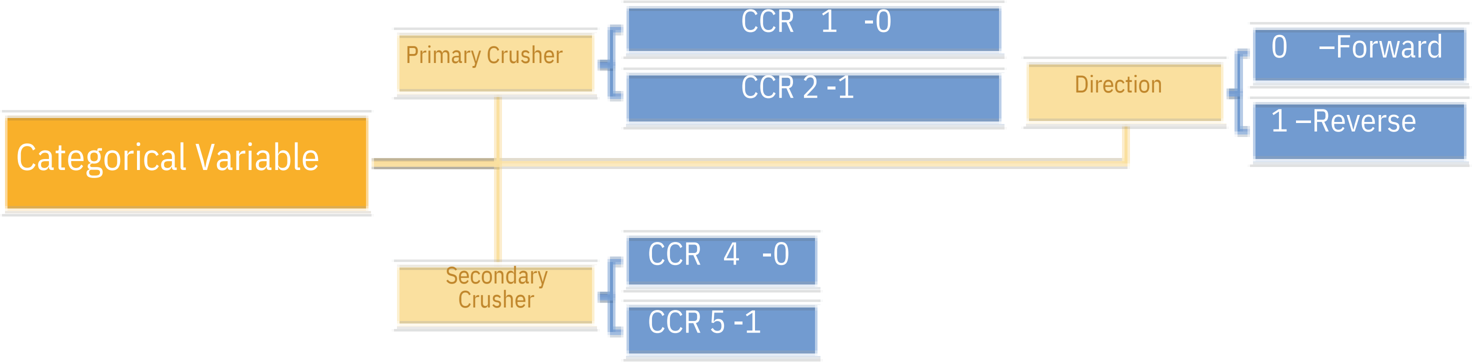
•The second screenshot shows the first five data sample of few input parameter

	Date	Type of Blend	VM	Moisture	Ash	S	C	N	H	CSN	...	Initial Moisture	Primary Crusher	Running Time (Min)	Direction	Coal raised	Secondary Crusher	Running Time (Min).1
0	2020-06-01	A	25.42	10.70	15.43	0.538944	76.205019	1.554112	4.428799	6.0	...	9.18	0	400	0	2400.0	0	400
1	2020-06-01	A	25.88	11.60	15.33	0.538944	76.205019	1.554112	4.428799	6.0	...	9.8	0	264	1	1700.7	1	267
2	2020-06-01	A	25.00	12.43	13.32	0.538944	76.205019	1.554112	4.428799	6.0	...	9.49	0	104	1	675.0	1	104
3	2020-06-02	A	27.28	12.00	13.85	0.538944	76.205019	1.554112	4.428799	6.0	...	0	0	0	1	0.0	0	0
4	2020-06-02	A	26.32	11.94	13.36	0.538944	76.205019	1.554112	4.428799	6.0	...	9.66	0	390	0	2530.0	0	390

Data Dictionary

				Description		
				Detail	Sample	Unit
Parameters	Coal Blend Parameter	1	VM	This parameter shows the volatile matter percentage in coal blend	24,56	%
		2	Ash	This parameter shows the ash percentage in coal blend	15.4	%
		3	Moisture	This parameter shows the moisture content in coal blend	10.7	%
		4	S, C, N, H	This parameter shows the percentage of individual component of specified elements	0.54, 76.21,1.55, 4.43	%
		5	Contraction	This parameter shows the percentage of contraction undergone by the coal cake	-17	%
		6	Expansion	This parameter shows the percentage of expansion undergone by the coal cake	31	%
		7	Max Fluidity	This parameter shows the max fluidity exhibited by the coal cake	365	Dial Division per Min
		8	Vit%	This parameter shows the vitrinite content in coal blend	54.17	%
		9	MMR	This parameter shows the mean max reflectance of coal blend	1.12	NA
	Crusher Parameter	1	Running Time	This parameter shows the total running time of each crusher	143	Min
		2	Direction	This parameter shows the direction of rotation of crusher	F	NA
		3	Coal Raised	This parameter shows the tonnage of coal passed through crusher	2537	Tons

Categorization of Discrete Variables –Label Encoding



* CCR –Coal Crusher

Data Distribution of Crushing Fineness: + 5mm particle size of crushed coal

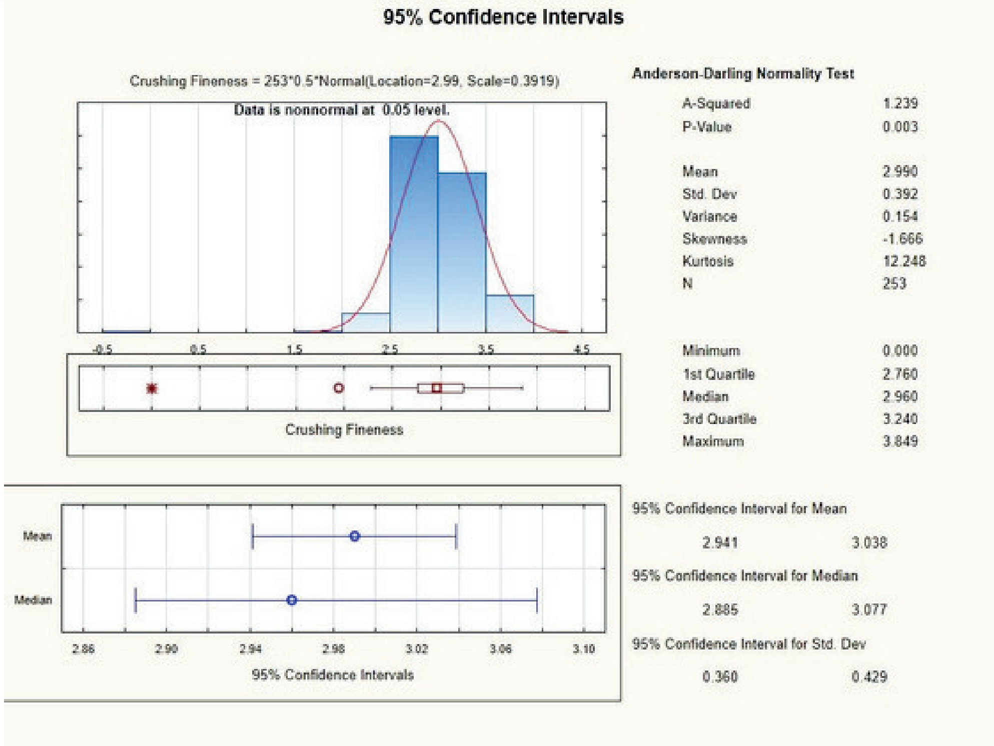


Figure-1

Fig-1

Description statistics of raw data of + 5mm particle size Box and Whisker Plot of + 5mm particle size wrt to blends

Data Distribution of Crushing Fineness: + 5mm particle size of crushed coal

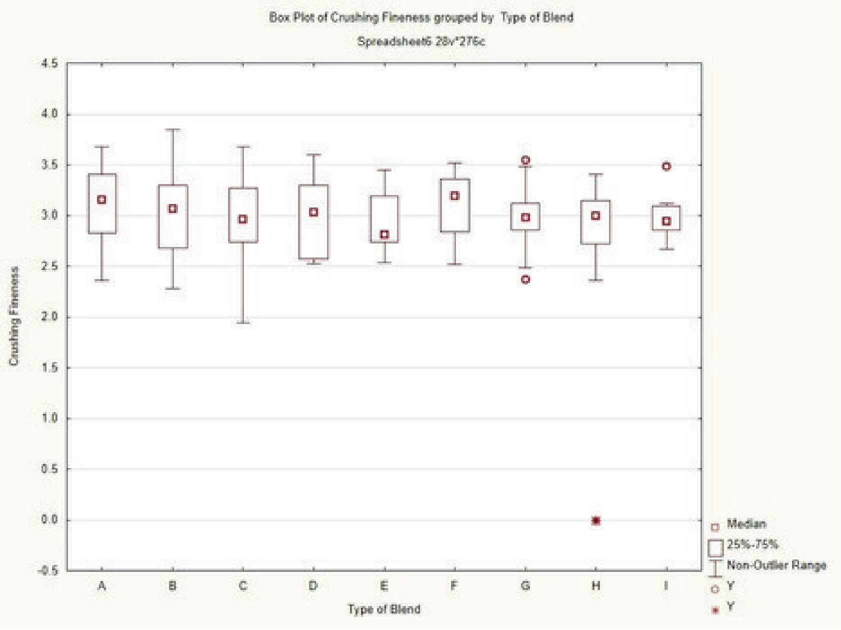


Figure-2

The histogram shows distribution of + 5mm particle sizemean of 2.99 % and SD of 0.392

Blend –wise distribution of + 5mm particle size

Data Preparation : Refining Percentage of greater than 5mm particle size Data set

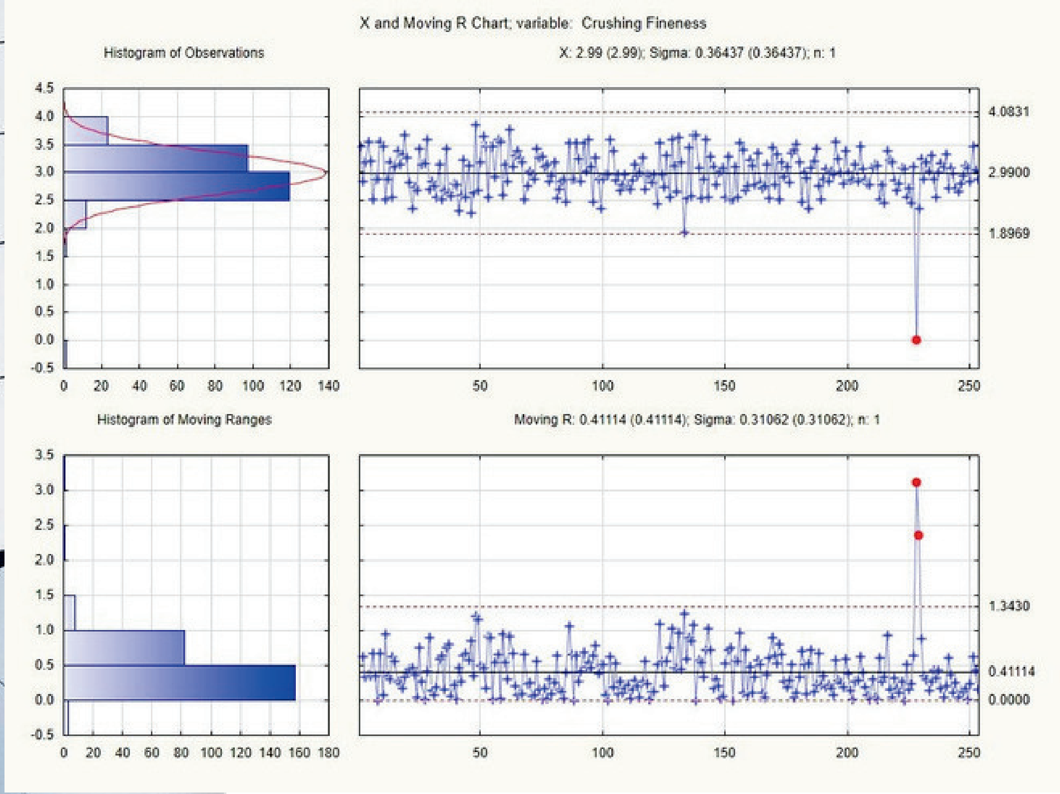


Figure-3

Date points	253
Time period	01/06/2020 –31/08/2020
Mean	2.99 %
Standard Deviation	0.392
Defect Detection	• Beyond UCL and LCL • Process Parameter – Above 5mm particle size
Outliers	Greater than 6 mm particle size

Table -1

Fig-3 Control Chart of raw data of + 5mm particle

Table-1 Specification of Data set

Data Preparation : Refining Percentage of greater than 5mm particle size Data set

Date points	253
Time period	01/06/2020 –31/08/2020
Mean	2.99 %
Standard Deviation	0.392
Defect Detection	• Beyond UCL and LCL • Process Parameter – Above 5mm particle size
Outliers	Greater than 6 mm particle size

Table -1

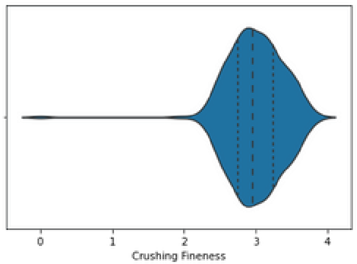
Fig-3 Control Chart of raw data of + 5mm particle

Table-1 Specification of Data set

Data Preparation: Cleaning of Data

1 2 3 4

Standardization:
The entire data set was standardized to have uniformity



Outliers:
The violin plot and box plot were plotted to remove outliers

Remove missing Values:
The output parameter Crushing Fineness count is 253 out of which 23 were missing points

```
df.isnull().sum()
Crushing Fineness        23
dtype: int64
```

Correct Datatype:
The output parameter Crushing Fineness is float64

```
27  Crushing Fineness     253 non-null    float64
```

```
df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 276 entries, 0 to 275
Data columns (total 28 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   Date                  276 non-null    datetime64[ns]
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 11  Expansion             276 non-null    int64
 12  Max. Fluidity         276 non-null    int64
 13  Vit%                  276 non-null    float64
 14  MMR                   276 non-null    float64
 15  -0.5                  251 non-null    float64
 16  -3.15                 251 non-null    float64
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 18  Initial Moisture      273 non-null    object
 19  Primary Crusher       276 non-null    int64
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 21  Direction             276 non-null    int64
 22  Coal raised           269 non-null    float64
 23  Secondary Crusher     276 non-null    int64
 24  Running Time (Min).1  276 non-null    int64
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 26  Coal raised.1         269 non-null    float64
 27  Crushing Fineness     253 non-null    float64
dtypes: datetime64[ns](1), float64(16), int64(9), object(2)
memory usage: 60.5+ KB
```

Before Cleaning data set with outliers

```
df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 230 entries, 0 to 229
Data columns (total 28 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   Date                  230 non-null    datetime64[ns]
 1   Type of Blend         230 non-null    object
 2   VM                    230 non-null    float64
 3   Moisture              230 non-null    float64
 4   Ash                   230 non-null    float64
 5   S                     230 non-null    float64
 6   C                     230 non-null    float64
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 9   CSN                   230 non-null    float64
 10  Contraction           230 non-null    int64
 11  Expansion             230 non-null    int64
 12  Max. Fluidity         230 non-null    int64
 13  Vit%                  230 non-null    float64
 14  MMR                   230 non-null    float64
 15  F1                    230 non-null    float64
 16  F2                    230 non-null    float64
 17  TPH CC 11             230 non-null    int64
 18  Initial Moisture      230 non-null    object
 19  PC                    230 non-null    int64
 20  Running Time (Min)    230 non-null    int64
 21  Direction1            230 non-null    int64
 22  Coal raised           230 non-null    float64
 23  SC                    230 non-null    int64
 24  Running Time (Min).1  230 non-null    int64
 25  Direction2            230 non-null    int64
 26  Coal raised.1         230 non-null    float64
 27  Crushing Fineness     230 non-null    float64
dtypes: datetime64[ns](1), float64(15), int64(10), object(2)
memory usage: 50.4+ KB
```

AfterCleaning data set elimination of outliers

Utilization of commands on data set after cleaning the data set

```
df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 230 entries, 0 to 229
Data columns (total 28 columns):
 #   Column                 Non-Null Count  Dtype
---  ------                 --------------  -----
 0   Date                   230 non-null    datetime64[ns]
 1   Type of Blend          230 non-null    object
 2   VM                     230 non-null    float64
 3   Moisture               230 non-null    float64
 4   Ash                    230 non-null    float64
 5   S                      230 non-null    float64
 6   C                      230 non-null    float64
 7   N                      230 non-null    float64
 8   H                      230 non-null    float64
 9   CSN                    230 non-null    float64
 10  Contraction            230 non-null    int64
 11  Expansion              230 non-null    int64
 12  Max. Fluidity          230 non-null    int64
 13  Vit%                   230 non-null    float64
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 26  Coal raised.1          230 non-null    float64
 27  Crushing Fineness      230 non-null    float64
dtypes: datetime64[ns](1), float64(15), int64(10), object(2)
memory usage: 50.4+ KB
```

AfterCleaning data set elimination of outliers

Utilization of commands on data set after cleaning the data set

TATA

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Refining Input Parameter

```
df.describe()
```

	VM	Moisture	Ash	S	C	N	H	CSN	Contraction	Expansion	...	TPH CC 11
count	261.000000	263.000000	261.000000	276.000000	276.000000	276.000000	276.000000	273.000000	276.000000	276.000000	...	276.0
mean	25.684138	11.762129	12.452559	0.548902	76.739947	1.623451	4.429758	5.780220	-29.510870	14.423913	...	400.0
std	0.678377	0.593167	0.747546	0.022896	0.604814	0.066076	0.026347	0.308061	2.788918	6.568078	...	0.0
min	23.410000	10.340000	10.160000	0.521417	76.162371	1.554112	4.398615	5.000000	-35.000000	-7.000000	...	400.0
25%	25.220000	11.420000	11.910000	0.538944	76.205019	1.571369	4.405596	5.500000	-31.000000	11.000000	...	400.0
50%	25.730000	11.690000	12.480000	0.541374	76.284299	1.588312	4.428799	6.000000	-29.500000	14.000000	...	400.0
75%	26.160000	12.000000	12.920000	0.548653	77.381381	1.651836	4.442237	6.000000	-28.000000	18.000000	...	400.0
max	27.580000	15.040000	15.430000	0.593800	77.598464	1.770693	4.497451	6.000000	-23.000000	33.000000	...	400.0

Before Cleaning data set with outliers

Refining Input Parameter

The outliers from each input parameter were removed

```
df.describe()
```

	VM	Moisture	Ash	S	C	N	H	CSN	Contraction	Expansion	...	TPH CC 11
count	230.000000	230.000000	230.000000	230.000000	230.000000	230.000000	230.000000	230.000000	230.000000	230.000000	...	230.0
mean	25.680957	11.755565	12.412904	0.549601	76.766029	1.627916	4.430272	5.778261	-29.543478	14.256522	...	400.0
std	0.665931	0.590590	0.700615	0.023492	0.608626	0.065862	0.026855	0.304201	2.866053	6.489449	...	0.0
min	23.410000	10.340000	10.160000	0.521417	76.162371	1.554112	4.398615	5.000000	-35.000000	-7.000000	...	400.0
25%	25.212500	11.410000	11.882500	0.538944	76.205019	1.571369	4.405596	5.500000	-31.000000	10.250000	...	400.0
50%	25.730000	11.670000	12.450000	0.541374	76.284299	1.588312	4.428799	6.000000	-29.500000	14.000000	...	400.0
75%	26.160000	11.987500	12.907500	0.548653	77.381381	1.665917	4.442237	6.000000	-28.000000	18.000000	...	400.0
max	27.580000	15.040000	13.940000	0.593800	77.598464	1.770693	4.497451	6.000000	-23.000000	33.000000	...	400.0

AfterCleaning data set elimination of outliers

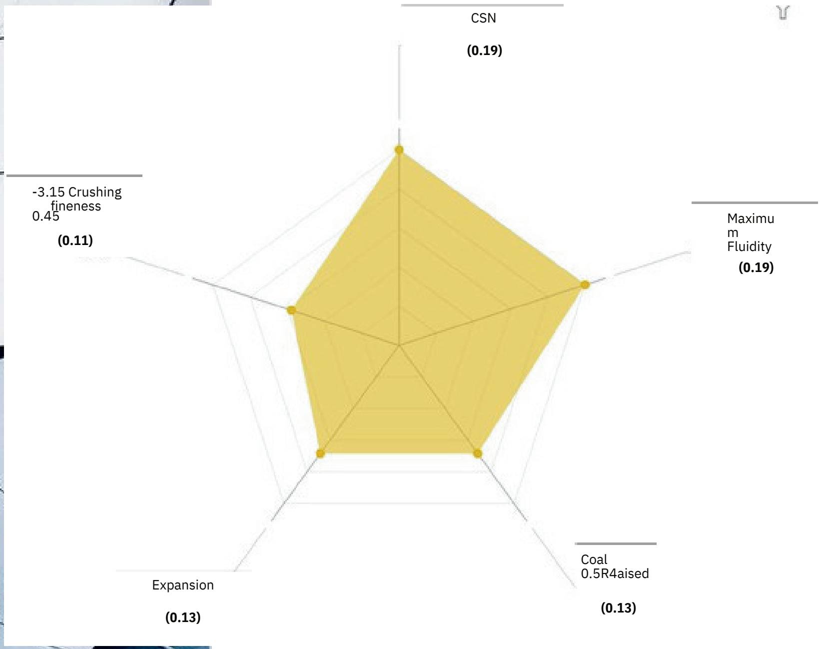
After

3. ANALYZE

Preparation of Correlation Univariate Analysis ● Bivariate Analyses ●
Matrix ● Multivariate Analysis

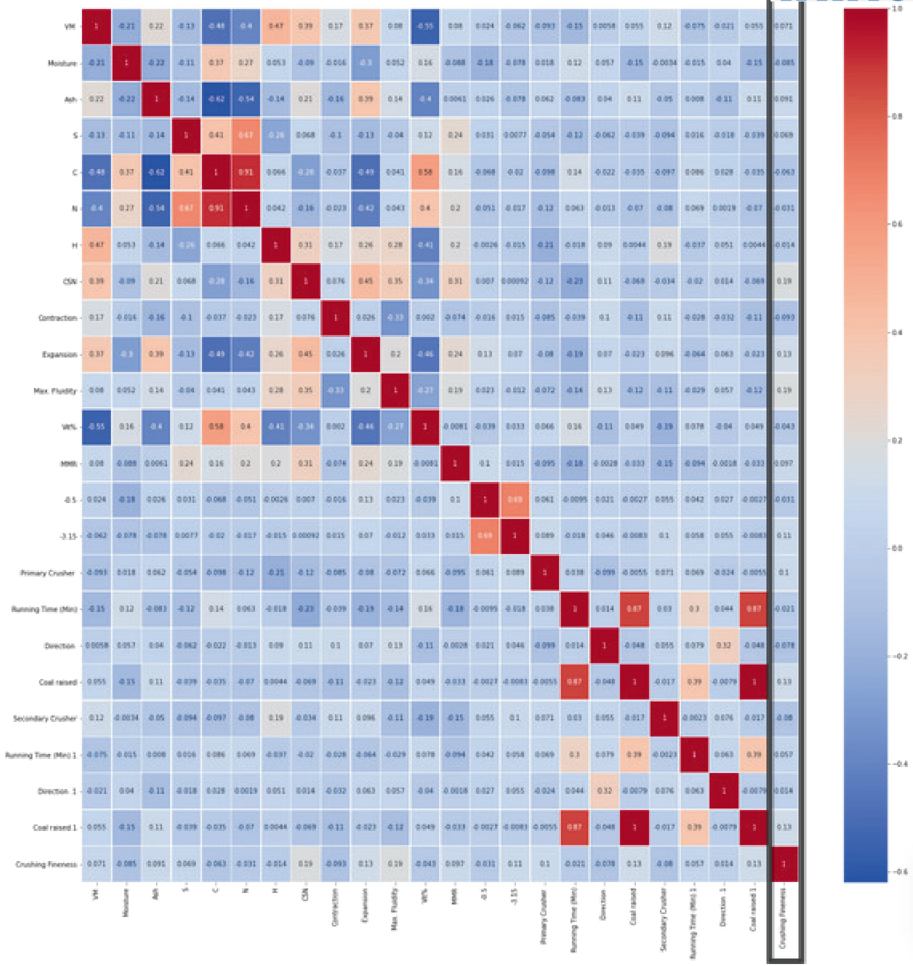
Correlation Matrix of independent variables wrt to Crushing Fineness

Filtering Features having correlation value greater than 0.05



Correlation Matrix of independent variables wrt to Crushing Fineness

Correlation matrix between features



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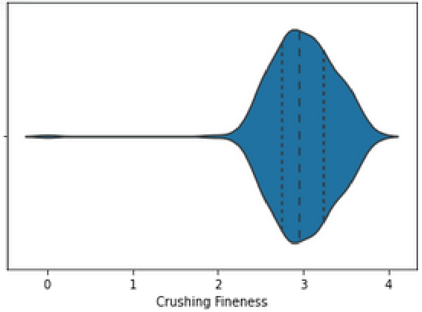
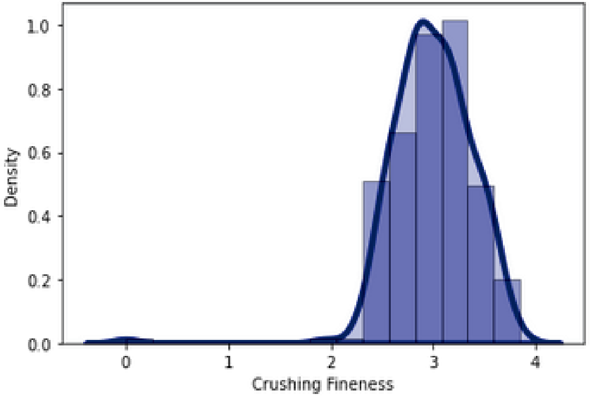
Univariate Analysis : Output Parameter

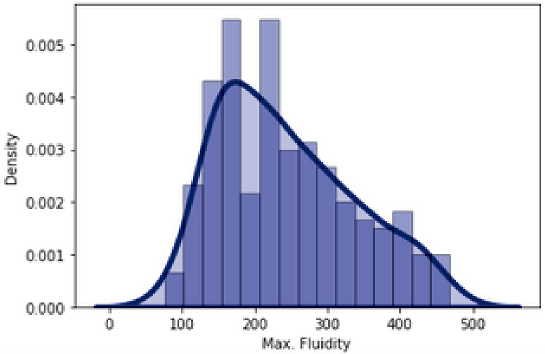


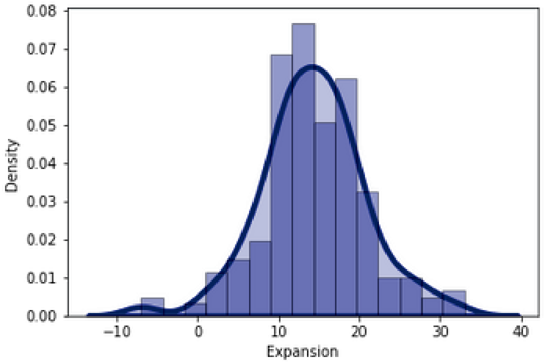
Violin Plot of output parameter + 5 mm crushed coal was plotted



- Histogram plot of output parameter + 5 mm crushed coal was plotted
- This shows normally distributed data set of output parameter

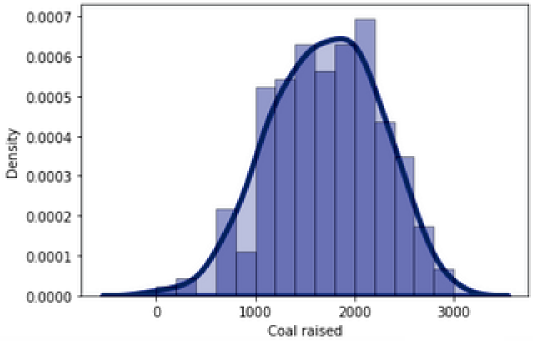
The histogram plot of Max Fluidity as input parameter was plotted to see the normal distribution of the parameter





The histogram plot of Expansion as input parameter was plotted to see the normal distribution of the parameter

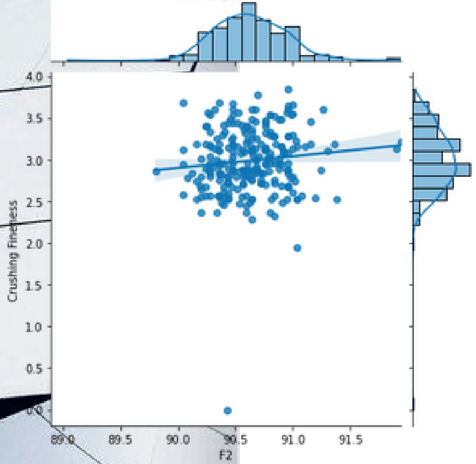
The histogram plot of Coal Raised as input parameter was plotted to see the normal distribution of the parameter



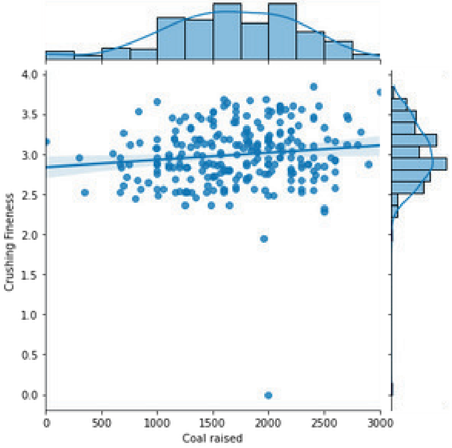
Histogram plots of input parameter

Bivariate Analysis : Blends Feature variation wrt output parameter (Blend, Crusher Features)

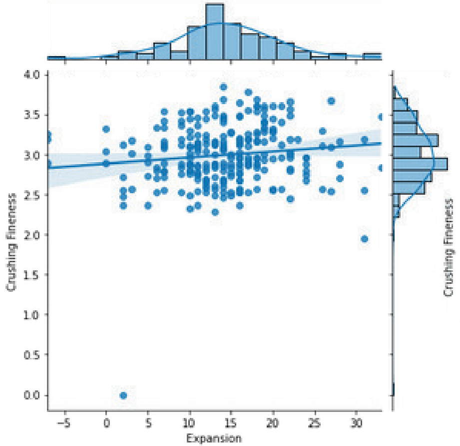
Properties coming from Correlation Matrix



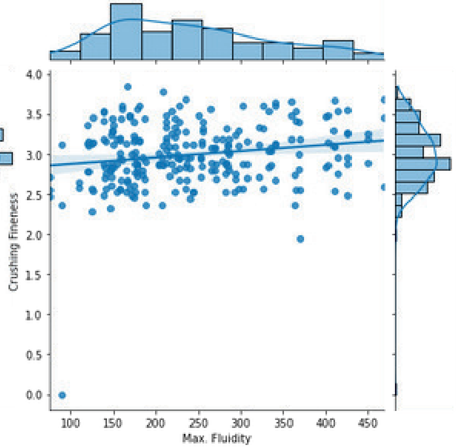
Positive correlation between - 3.15 and crushing Fineness



Positive correlation between Coal Raised and crushing fineness

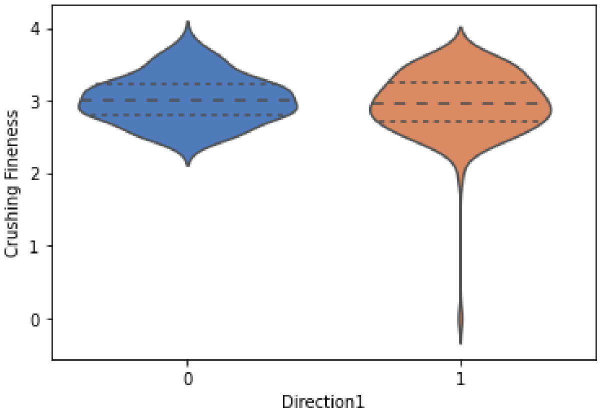


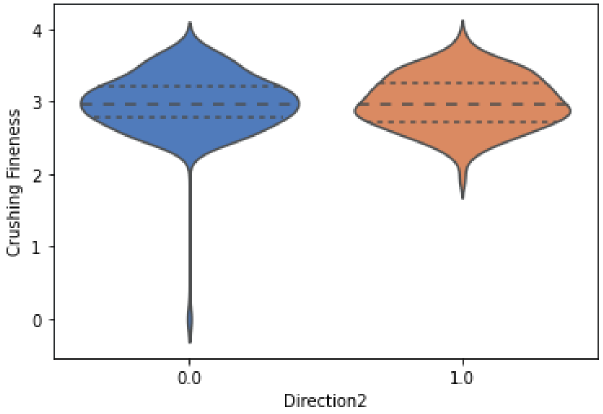
Positive correlation between Expansion % and crushing fineness



Positive correlation between Max Fluidity and Crushing Fineness

Scatter plot have been plotted between input parameters like -3.15, coal raised, Expansion percentage, Max Fluidity respectively with Crushing Fineness to evaluate variation





1. Violin plot for crushing Fineness between direction 0 which is Forward and 1 which is Reverse. (For Primary Crusher House)
2. . When Crusher was running in forward direction, comparatively more % of +5mm is generated
No distinctive inference could be obtained

1. Violin plot for crushing Fineness between direction 0 which is Forward and 1 which is Reverse. (For Secondary Crusher House)
2. No distinctive inference could be obtained

Bivariate Analysis : Categorical Variable

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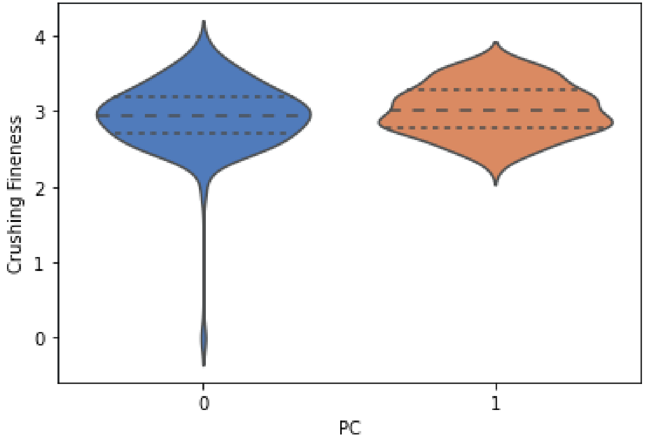

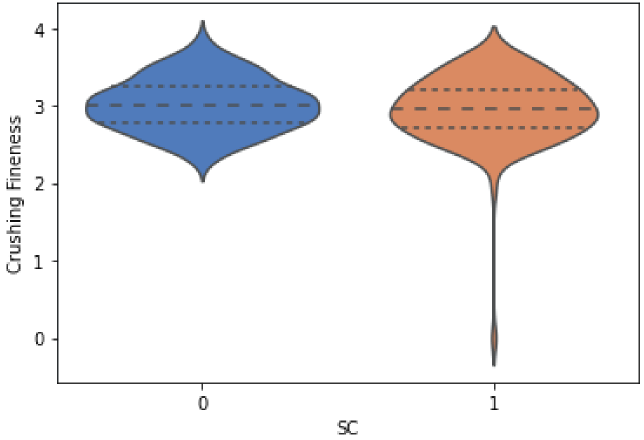

1. Violin plot for crushing Fineness between Primary Crusher, 0 which is CCR 1 and 1 which is CCR 2.
2. When CCR 2 Crusher was running, comparatively more % of +5mm is generated
3. No distinctive inference could be obtained

1. Violin plot for crushing Fineness between Secondary Crusher, 0 which is CCR 4 and 1 which is CCR 5.
2. When CCR 4 Crusher was running, comparatively more % of +5mm is generated
3. No distinctive inference could be obtained

Bivariate Analysis : Categorical Variable

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Correlation Matrix of independent variables wrt to Crushing Fineness

“

1. The highlighted portion : Correlation value between input as well as output parameter.
2. Parameters like -3.15 coal crushed fraction, coal raised, Expansion percentage, Max Fluidity with Crushing Fineness have correlation value greater than 0.05 showing weak correlation between them.
3. Input Parameters : (VM and C), (VM and Vit%), (Expansion and C), (Vit% and Expansion), (C and Ash), (N and Ash) are strongly correlated with each other

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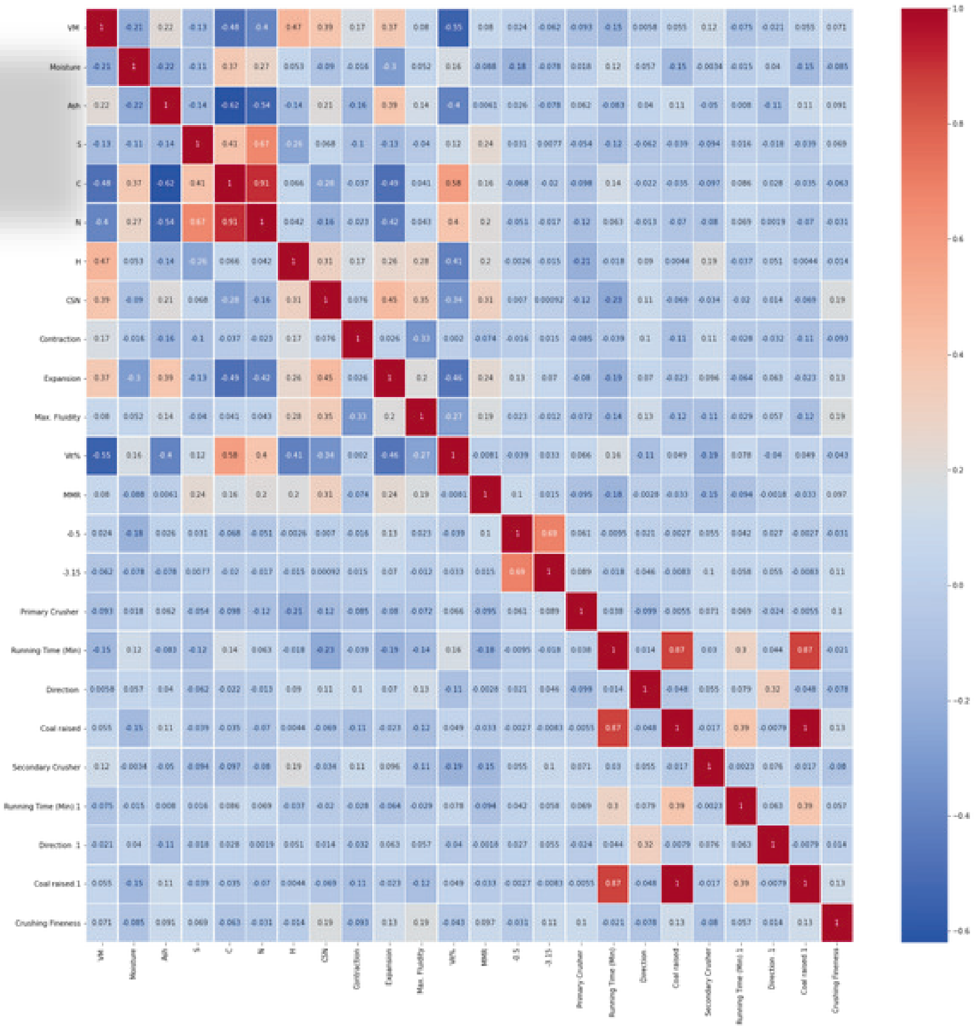
Correlation Matrix of independent variables wrt to Crushing Fineness



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Conclusion

	CRUSHING FINENESS			
Theoretical	Positive correlation with Max Fluidity	Positive correlation with % Expansion	Negative correlation with -3.15	Positive correlation with Coal Raised
DEVIATION				
Practical	Weak Positive correlation with Max Fluidity	Weak positive correlation with % Expansion	Wrong correlation	Weak positive correlation with Coal Raised

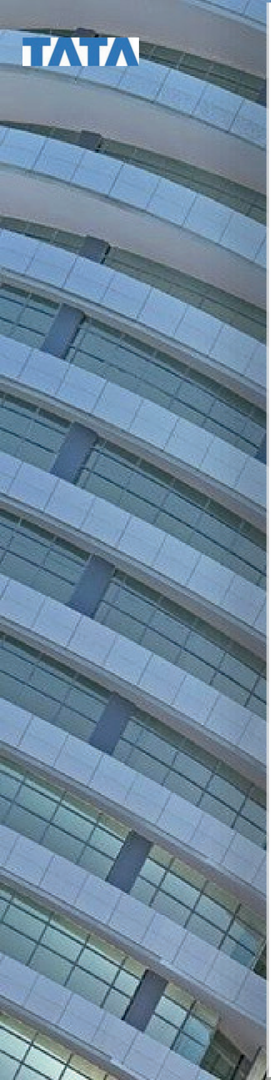
Deviations due to limited data set.
Parameter other than the theoretical ones could be a significant predictor The categorical features should be analyzed further for proper inference

Conclusion

	CRUSHING FINENESS			
Theoretical	Positive correlation with Max Fluidity	Positive correlation with % Expansion	Negative correlation with -3.15	Positive correlation with Coal Raised
DEVIATION				
Practical	Weak Positive correlation with Max Fluidity	Weak positive correlation with % Expansion	Wrong correlation	Weak positive correlation with Coal Raised

Action Plan

- Expansion of Data set for each blend
- Parameter analysis on increased data of individual coal constituting blend to obtain significant predictor
- The input parameter if correlated can be merged and a proxy parameter could be created.



THANK YOU