Production Analysis by Modelling of Unfinished Product Generation in Rolling Mill of Steel Industry

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***Abstract* – Every Steel Industry produces unfinished products along with finished products. In Merchant Mill of a Steel Plant uses hot rolling process to produce Merchant Products like Angles, Channels, Beams, Bars and T.M.T. bars, etc. In this process billets are heated at 1200 ± 50 ^{0}C in Reheating Furnace and passes between rollers of stand. Merchant Mill sometimes generates unfinished products (Cobbles), which results in failure of the process technology. This problem is responsible for Mill trip– which thus stops the rolling for some time. It is observed – approximately 2 to 4 cobbles generated per day in rolling hour. We found, there is increase in load of stand and decrease in temperature of heated billets. Hence for minimization of cobbles, Radiation Pyrometer is installed after rolling stand in existing system. The data such as temperatures of billets and corresponding load of the stand are collected through the adaptive control system through monitor and are analyzed by software IBM SPSS Statistics 20. Result of the analysis consists of Mean, Standard deviation, Correlation and Regression coefficient of load and temperatures. The finding shows that there is a significant negative relationship between Load and Temperature i.e. load is inversely proportional to the temperature. Hence optimum temperature must be required for continuous & uniform rolling process in steel industry. By this modification there is increased productivity, quality parameter of the merchant products and profit of the Mill.**

Key words: Cobble, Radiation Pyrometer, Angles, Channels, Rolling.

I. INTRODUCTION

Merchant mill operation is based on hot rolling process, which produces, Angles, Channels, Beams Bars, TMT Bars. In this study we measure the load and temperature of heated soaked billets before and after passing between the rolling stands. For load measurement, ammeter instrument is installed in the process & for measurement of temperature of billets uses thermocouple. For the data collection related to generation of unfinished products – "Instrumentation method" is applied, we use "Radiation Pyrometer instrument" which measures surface temperature of the heated billets, which is passed between the rollers while rolling. It is a non- contact temperature sensor that infers the temperature of an object by detecting its naturally emitted thermal radiation by the surface of very hot object. An optical system collects the infrared thermal radiation of the heated object and focuses it on detector. The detector converts the heat energy into electrical signal to drive the temperature display. Also we found the impact of load on rollers by instrument Ammeter.[8]

A. Merchant Mill

The Merchant Mill is semi continuous high capacity mill, which is designed to roll 0.5 to 1.0 MT per annum of finished products.[8] The mill consists mainly three sections as-

- Re-heating furnace
- The mills stands and cooling beds
- Finishing zone & shipping

Raw materials used are billets of size (in mm) 90×90, 95×95, 100×100, 110×110, 105×105 and length ranging from 5 m to 6 meter. Billets are supplied from stock yards by Electromagnetic Cranes to the loading device, to push the billets on the furnace approach roll table. It is designed to receive billets from the loading device and deliver them to the furnaces. The furnace charging pusher, pushes the billets after evolving from the approach roll table into the furnace and moves the entire charge inside the furnace and thus pushing the heated billets on to the delivery roll table at the discharge side of the furnace.[9]

B. Reheating furnace and its process-

In merchant mill there is a Continuous Pusher Type Reheating furnaces, Gas fire burners, 3 zone Furnaces (Soaking Zone, Heating Zone, Preheating Zone), capacity 60 ton/hrs (heated billets supply for Rolling).In reheating furnace, the cold billets are loaded in "loading device" by overhead crane (O.H.C.) from billets yard as per quality requirement of mill. By delivery roll table, the billets has been sending into charging side of the furnace, after this the billets are charged by use of "charging device", through pulpit operation manually (electrical & mechanical device)

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in standard manner.[1] The charged billets are heated and soaked in furnace at 1200 ± 50 ^{0}C after this; heated billets are pushed by charging pusher mechanism than discharged heated billets on delivery roll table. These heated billets are passed between rollers (mechanical stand) and by hot rolling process it gives finished merchant products.

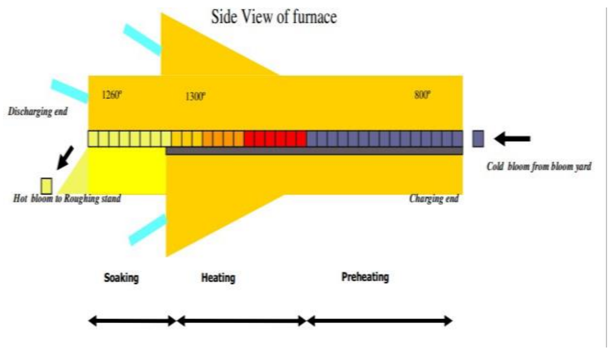


Fig. 1. Cross-section of R.H.F. [7]

II. RESEARCH METHODOLOGY

A. *Problem Identified*

The Merchant Mill of Steel Plant produces finished products as per Customers & Market Requirement. But sometimes produces unfinished product (cobbles) due to unexpected problem in Hot Rolling Process. These problem arises due to failure of lubrication system in rolling stands, cooling system in stands, electric failure, uneven temperature of billets, mechanical problem and high rolling speed etc. This problem impact production qualitatively as well as quantitatively, loss of Human effort, raw material wastage and cause breakdown of mill. Furthermore it takes a lot of time to start rolling again and hence cause high production loss.

B. *Statement of Problem:*

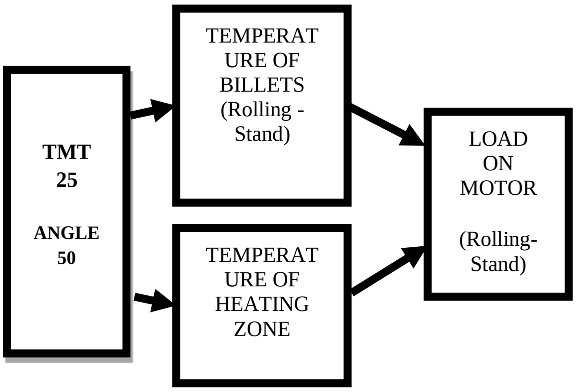
The Mill was undergoing "loss of production" due to variations in Hot Rolling process Parameters. Following problems were identified:-

- Variability in quality standards of finished products in same profile.
- Change in operational parameter during rolling process of mill.
- Increasing the cobbles in rolling stands, it gives unfinished product.
- Roll breakage due to uneven rate of rolling & lack of maintenance.
- Generation of excess load in rolling stand during operation.
- High speed rolling gives different types of breakdowns.
- Uneven temperature of heated billets supply from furnace.

C. *Research Objective:*

- To analyze the relationship between the temperature and load of billets at stand.
- To analyze the relationship between the Heating zone temperature and load on motor of stand.
- To develop a model under the Production of bar and Angle.

D. *Research frame work:*



The data are collected for TMT 25mm bar and Angle 50mm production .Under these conditions, the Billet temperature at 2nd stand during passes between roller, Heating zone temperature and Load on Stand 2 motor are measured with the help of Control devices. These data are analyzed in order to determine the relationship between them.

III. DATA COLLECTION AND ANALYSIS

The primary data is collected directly from the Fixed Type Radiation Pyrometer installed near "stand 2" of the reheating furnace & mill operation. The variables measured in the process of data collection are as follows:-

- Temperature of Billet at stand 2 in ^{0}C = T_s
- Temperature of heating zone in ^{0}C = T_h
- Load of roller in Ampere = L

Where, Load of roller (L) is dependent on other two variables i.e. Temperature of billet in "stand 2" (T_s) & Temperature of heating zone (T_h). Hence, Load of roller (L) is considered as Dependent variable and other two are Independent variables.

- **Heating zone temperature (T_h):** The temperature of reheating furnace in which the billets are heated at desired rolling temperature (hot rolling process).
- **Temperature of billet at stand 2 (T_s):** It is the measured temperature of billets at the point when the billets are passing from stand 2.
- **Load of roller (L):** The usage of current to drive the motor of stand 2 which is used to rotate the roller and to transfer the billets for further process. It is measured in **Ampere**.

These variables are measured for the merchant products of TMT-25mm and No. of observation taken under each condition is **N = 30**

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TABLE I. Data collection during production of TMT 25 mm bar

S.no.	Load of Rollers (Ampere)	Billet Temperature at (stand 2) ^{0}C	Heating zone Temperature ^{0}C
1	825	1048	1250
2	847	1052	1248
3	852	1065	1252
4	844	1047	1260
5	870	1061	1240
6	905	1070	1242
7	897	1072	1238
8	875	1078	1230
9	847	1085	1241
10	910	1092	1247
11	842	1103	1250
12	825	1110	1253
13	832	1103	1260
14	839	1097	1265
15	915	1082	1267
16	918	1087	1270
17	925	1067	1253
18	947	1073	1148
19	951	1045	1228
20	910	1049	1232
21	893	1035	1233
22	857	1038	1242
23	872	1042	1244
24	885	1043	1247
25	891	1029	1252
26	905	1045	1255
27	915	997	1203
28	925	970	1237
29	870	968	1240
30	910	1080	1248

TABLE II. Data collection during production of ANGLE - 50mm

S.no.	Load of Rollers (Ampere)	Billet Temperature at (stand 2) ^{0}C	Heating zone Temperature ^{0}C
1	718	1047	1226
2	720	1042	1220
3	716	1050	1228
4	717	1052	1218
5	715	1057	1228
6	715	1062	1252
7	725	1063	1222
8	735	1074	1221
9	711	1068	1218
10	754	1067	1220
11	729	1080	1211
12	711	1082	1203
13	720	1058	1210
14	722	1057	1220
15	757	1053	1210
16	720	1047	1221
17	750	1053	1225
18	745	1055	1232
19	725	1058	1230
20	715	1077	1235
21	712	1080	1233
22	711	1082	1245
23	715	1078	1240
24	712	1082	1230
25	715	1083	1222
26	722	1075	1228
27	718	1077	1231
28	725	1052	1229
29	717	1078	1233
30	735	1073	1215

A. Data Analysis

The tool used for the analysis of data collected at different conditions is **IBM SPSS Statistics 2.0.** The tool is used to analyze the following:

- To determine the Descriptive analysis of the readings.
- To determine **Correlation** between all the variables.
- To perform **Multiple regression analysis**. This is used to formulate formula under these 2 conditions.

i. Analysis of TMT 25 mm bar:

TABLE III. Descriptive analysis –

Descriptive Statistics						
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Load of Rollers (Ampere)	30	126	825	951	883.30	36.321
Heating zone Temperature	30	122	1148	1270	1242.50	22.261
Billet Temperature at (stand 2)	30	142	968	1110	1057.77	35.064

TABLE IV. Correlation analysis –

Correlations				
		Load of Rollers (Ampere)	**Billet Temperature at (stand 2)**	**Heating zone Temperature**
Load of Rollers (Ampere)	Pearson Correlation	1	-0.261	-0.442*
	Sig. (2-tailed)		0.164	0.015
	N	30	30	30
Billet Temperature at (stand 2)	Pearson Correlation	-0.261	1	0.238
	Sig. (2-tailed)	0.164		0.206
	N	30	30	30
Heating zone Temperature	Pearson Correlation	-0.442*	0.238	1
	Sig. (2-tailed)	0.015	0.206	
	N	30	30	30

- Correlation is significant at the 0.05 level (2-tailed).

With the help of Correlation, we can determine how strong the relationship exists between these variables. As we can observe from the table:

- There is a weak negative linear relationship between load of rollers (L) and billet temperature at stand 2 (T_s) i.e. **-0.261.**
- There is a moderate negative linear relationship between load of rollers (L) and temperature of heating zone (T_h) i.e. **-0.442.**

TABLE V. Regression analysis –

Model	Unstandard Coefficients		Standardized Coefficients	T	Sig.	Correlations		
	B	Std. Error	Beta			zero-order	Parital	Part
(Constant)	1879.938	360.764		5.211	0			
Billet Temp at (Stand 2)	-171	0.181	-165	-943	0.354	-261	-179	-160
Heating Zone Temp	-657	0.285	-402	-2.301	0.29	-442	-405	-391

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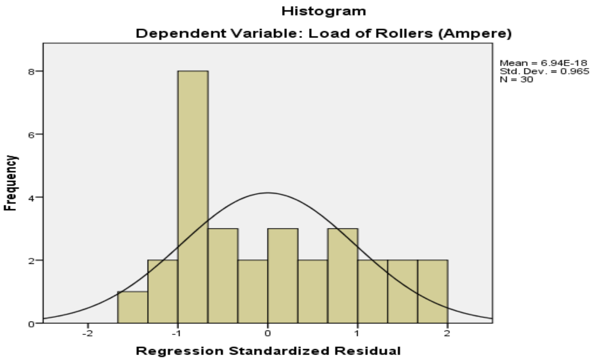

Fig. 2. Bell shape curve graph for regression analysis

Bell shape curve in histogram fulfills the assumption of multiple regressions that is "normality of the error term distribution".

According to regression coefficient table we can formulate the formula for the relationship between load of rollers (L) in term of Temperature of billet at stand 2 (T_s) and temperature of heating zone (T_h)

$$\textbf{Load of roller (L)} = a + b_1 x_1 + b_2 x_2$$

$$L = 1879.938 - 0.171 \times T_s - 0.657 \times T_h$$

where **1879.938** is constant called intercept and is denoted by **a.**

ii. Analysis of Angle

Model		Unstandardized Coefficients		Standardized Coefficients		Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	1393.291	306.689		.543	000			
	Billet Temperature at (stand 2)	-.253	.178	-.254	1.419	167	-.291	.263	.251
	Heating zone Temperature	-.327	.220	-.266	1.487	149	-.302	.275	.263

Coefficients[a]

a. Dependent Variable: Load of Rollers (Ampere)

TABLE VI. Descriptive analysis –

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Load of Rollers (Ampere)	30	46	711	757	723.40	12.939
Billet Temperature at (stand 2)	30	41	1042	1083	1065.40	12.982
Heating zone Temperature	30	49	1203	1252	1225.20	10.526
Valid N (listwise)	30					

TABLE VII. Correlation analysis –

Correlations

		Load of Rollers (Ampere)	Billet Temperature at (stand 2)	Heating zone Temperature
Load of Rollers (Ampere)	Pearson Correlation	1	-.291	-.302
	Sig. (2-tailed)		.118	.105
	N	30	30	30
Billet Temperature at (stand 2)	Pearson Correlation	-.291	1	.142
	Sig. (2-tailed)	.118		.454
	N	30	30	30
Heating zone Temperature	Pearson Correlation	-.302	.142	1
	Sig. (2-tailed)	.105	.454	
	N	30	30	30

With the help of Correlation, we can determine how strong the relationship exists between these variables.

As we can observe from the table:

- There is a weak negative linear relationship between load of rollers (L) and billet temperature at stand 2 (T_s) i.e. -0.291.
- There is a moderate negative linear relationship between load of rollers (L) and temperature of heating zone (T_h) i.e. -0.302.

TABLE VIII. Regression analysis:

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
(Constant)	1393.291	306.689		4.543	.000			
Billet Temperature at (stand 2)	-.253	.178	-.254	-1.419	.167	-.291	-.263	-.251
Heating zone Temperature	-.327	.220	-.266	-1.487	.149	-.302	-.275	-.263

a. Dependent Variable: Load of Rollers (Ampere)

According to regression coefficient table we can formulate the formula for the relationship between **Load of rollers (L)** in term of **Temperature of billet at stand 2 (T_s)** and **Temperature of heating zone (T_h).**

$$\textbf{Load of roller (L)} = a + b_1 x_1 + b_2 x_2$$

$$L = 1393.291 - 0.253 \times T_s - 0.327 \times T_h$$

Where **1393.291** is constant called intercept and is denoted by **a**

B. *Production Analysis*

We have collected the data of amount of monthly production of merchant mill & respective unfinished products, before and after the installation of radiation pyrometer i.e. on Nov 2018. These are as follows:-

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i. Data Collection & Analysis before installation of Radiation Pyrometer

TABLE IX. Data Collection of Unfinished Product before installation of Radiation Pyrometer (2018-19)

S.no.	Month	Production/ year (Ton)	Total unfinished product/year (Ton)	Percentage of Unfinished product/year (%)
1.	Apr 2018	54283	232.50	0.42
2.	May 2018	54639	255.39	0.46
3.	June 2018	52399	200.27	0.38
4.	July 2018	34476	199.84	0.57
5.	Aug 2018	51906	209.14	0.40
6.	Sept 2018	52208	223.58	0.42
7.	Oct 2018	45934	189.50	0.41
8.	Nov 2018	51216	242.42	0.47
	Total	**395061 T**	**1752.64 T**	------
	Average	**49382.6 T**	**219.08 T**	**0.44%**

Data Analysis

We found that the generation of unfinished product in 8 months (from April 2018 to Nov 2018) is 1752.64 Ton which is on average **219.08 Ton/month**. Percentage of Cobble (unfinished products) generation was **0.44 %** of total finished products. Total production in 8 months was 395061 Ton/month i.e. 0.395 MT. Other reasons are not included here, which impact production. Hence there was a loss incurred-

Approximate Mean Production Loss (before installation) = **219.08 Ton / Month**

ii. Data Collection & Analysis after installation of Radiation Pyrometer

TABLE X. Data Collection of Unfinished Product after installation of Radiation Pyrometer (2018 -19)

S.no.	Month	Production / year (Ton)	Total unfinished product / year (Ton)	Percentage of Unfinished product/year (%)
1.	Dec 2018	45566	140.94	0.30
2.	Jan 2019	55286	123.58	0.22
3.	Feb 2019	52222	129.32	0.24
4.	Mar 2019	59207	112.18	0.18
5.	April 2019	41075	102.48	0.24
6.	May 2019	55026	80.75	0.14
7.	June 2019	35609	98.62	0.27
8.	July 2019	54228	70.84	0.13
	Total	**398219 T**	**858.71 T**	------
	Average	**49777.4 T**	**107.33 T**	**0.215 %**

Data Analysis after installation– IMPAC Radiation Pyrometer

A Digital Fixed type Radiation Pyrometer was installed on **27 Nov 2018 near stand 2, merchant mill, B.S.P.** Data was collected from the product Log book of mill and monthly report of production .We found that the generation of unfinished product in 8 months (from Dec 2018 to July 2019) is 858.71Ton which is on average **107.33 Ton/month**). Percentage of Cobble (unfinished products) generation was **0.215 %** of total finished products. This Data shows the decrease in cobble generation.

iii. *Graphical Analysis*

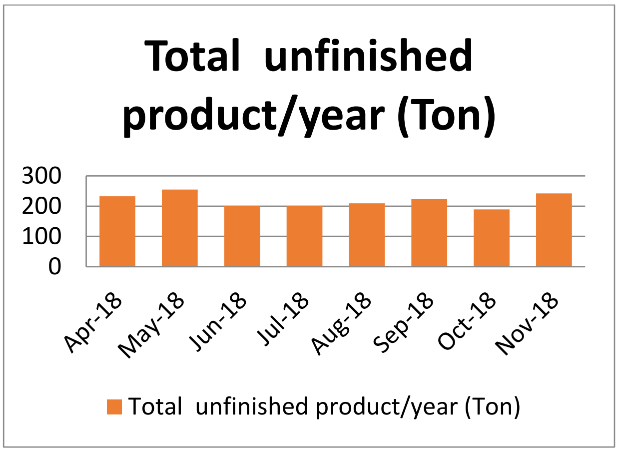

Fig 3. Bar graph representation of Cobble generation before installation of Radiation Pyrometer

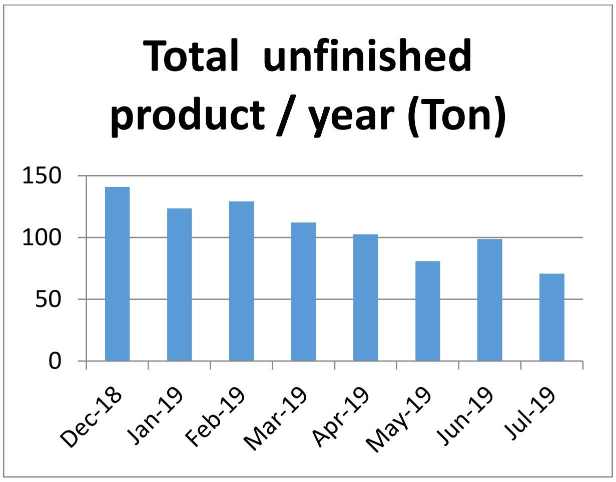

Fig 4. Bar graph representation of Cobble generation after installation of Radiation Pyrometer

iv. *Analysis of Increased Production*

Increased Production or Cobble reduction = Cobble generation before installation – Cobble generation after installation

Increased Production (Ton / month) = 219.08 – 107.33 = **111.75 Ton/month, i.e.0.23%**

IV. RESULT & DISCUSSIONS

Analysis of the collected data after installation of fixed type Digital Radiation Pyrometer model no. IMPAC IBA-5, signifies the load is inversely proportional to the temperature. This gives the new formula for calculating the generated load on rollers of stand. Also, Continuous monitoring the temperature of heated billets shows the minimum safe rolling temperature and safe load limit which must be set and maintained for continuous rolling.

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TABLE XI. Observed Load data after installation of Radiation pyrometer

Profile	Process Load (°C)	Safe Load setting (Amperes)
Angles	800 ± 50	1100
Bars	800 ± 50	1250

Benefits of analysis after installation of radiation pyrometer-

- Continuous monitoring the temperature of heated billets.
- Increased the productivity **111.75 Ton/month** and decreasing the production of unfinished product.
- Increased Production per year is **1341 Ton/yr.**

V. CONCLUSION

The generation of unfinished products along with the finished products gives loss of productivity. It was due to excess load generation in motor to operate rollers in rolling stand because of less temperature of heated billets in furnace. This problem solved by installation of "Radiation pyrometer" hence continuous & uniform observation became possible. After this installation increased productivity is observed approximately 111 Ton/ month and subsequent decrease in Cobbles. Also financial impact on the company is around 5.7 Crore Rs/ year by increased production.

Also our analysis with the help of tool – **IBM SPSS Statistics 2.0** of data – load and temperature, made it possible to standardize the present system in the merchant mill. The tool determined the correlation and multiple regression analysis, hence derived standard formula for all the products in the mill.

VI. FUTURE SCOPE

This instrument radiation pyrometer can be used as control process parameters for rolling in any steel industry. Formula derived in this study for the different profiles (angles, channels and bars) can be used to maximize production in the Rolling mill of Steel Plant

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