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 °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: Cobbles, 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.[9] 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/hr 500 °C (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)
in standard manner.\cite{1} The charged billets are heated and soaked in furnace at 1200 ± 50 °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.

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. This 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 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 °C = T_s
- Temperature of heating zone in °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
TABLE I. Data collection during production of TMT 25 mm bar

| S.no | Load of Rollers (Ampere) | Billet Temperature at (stand 2) °C | Heating zone Temperature °C |
|------|--------------------------|-----------------------------------|-----------------------------|
| 1    | 825                      | 1048                              | 1250                        |
| 2    | 847                      | 1052                              | 1248                        |
| 3    | 852                      | 1065                              | 1252                        |
| 4    | 844                      | 1047                              | 1250                        |
| 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) °C | Heating zone Temperature °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 – |
|-----------------------------------|
| 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 – |
|-----------------------------------|
| Load of Rollers (Ampere) | Pearson Correlation | Sig. (2-tailed) | N |
|--------------------------|---------------------|-----------------|---|
| Load of Rollers (Ampere) | 1 | -0.261 | -0.442 * |
| Sig. (2-tailed) | 0.164 | 0.238 |
| N | 30 | 30 | 30 |
| Heating zone Temperature | Pearson Correlation | Sig. (2-tailed) | N |
|--------------------------|---------------------|-----------------|---|
| Heating zone Temperature | -0.442 * | 0.206 | 1 |
| Sig. (2-tailed) | 0.15 | 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 (T₂) i.e. -0.261.
- There is a moderate negative linear relationship between load of rollers (L) and temperature of heating zone (T₃) i.e. -0.442.

| TABLE V. Regression analysis – |
|---------------------------------|
| Load of Rollers (Ampere) | R | Std. Error | Std. Coefficients | T | Sig. | Correlation |
|--------------------------|---|------------|-------------------|---|-----|------------|
| [Constant] | 1.879.938 | 140.764 | 5.211 | 0 | | |
| Billet Temp at (stand 2) | -171 | 0.181 | -165 | -0.043 | 0.354 | -261 | -1.79 | -0.60 |
| Heating Zone Temp | -657 | 0.285 | -402 | -2.301 | 0.29 | -442 | -0.405 | -391 |
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 \( T_h \)

\[
L = 1879.938 -0.171 \times T_s -0.657 \times T_h
\]

L = \text{constant called intercept and is denoted by } a.

### ii. Analysis of Angle

**TABLE VI.** Descriptive analysis –

| Description                  | 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         |

**TABLE VII.** Correlation analysis –

| Load of Rollers (Ampere) | Pearson Correlation | Sig. (2-tailed) | N  | Load of Rollers (Ampere) | Pearson Correlation | Sig. (2-tailed) | N  | Billet Temperature at (stand 2) | Pearson Correlation | Sig. (2-tailed) | N  | Heating zone Temperature | Pearson Correlation | Sig. (2-tailed) | N  |
|--------------------------|---------------------|-----------------|----|--------------------------|---------------------|-------------------|----|-------------------------------|---------------------|-----------------|----|--------------------------|---------------------|-----------------|----|
|                          |                     |                 |    |                          |                     |                   |    |                               |                     |                 |    |                         |                     |                 |    |
|                          |                     |                 |    |                          | 1                    | -0.291            | 0.05           | 30 |                          | -0.302             | 0.142           | 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:

| Model                              | Unstandardized Coefficients | Standardized Coefficients | B     | Std. Error | Beta  | Coefficients<sup>a</sup> | t     | Sig. (2-tailed) | Z    | Partial | Variable | Heating zone Temperature | T      | Sig. (2-tailed) | Partial | Part | Variance explained |
|------------------------------------|-----------------------------|---------------------------|-------|------------|-------|-------------------------|-------|----------------|------|---------|----------|------------------------|-------|-----------------|---------|------|-------------------|
| (Constant)                         | 1.139291                   | 1.139291                  | 1.139291 | 1.139291 | 1     | 0.000                   |       |                |      |         |          |                         |       |                 |         |      |                    |
| Billet Temperature at (stand 2)    | -.253                      | -.253                     | -.253  | -.253     | -.253 | -.253                   | -.253 | .000           |      |         |          | Billet Temperature at (stand 2) | -.253 | .000            |         |      |                    |
| Heating zone Temperature          | -.327                      | -.327                     | -.327  | -.327     | -.327 | -.327                   | -.327 | .000           |      |         |          | Heating zone Temperature | -.327 | .000            |         |      |                    |

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 \( T_h \)

\[
L = 1393.291-0.253 T_s -0.327 T_h
\]

L = \text{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:-
### 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 |         |                        | 1752.64 T                           |                                           |
| Average|        |                        | 49382.6 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/year 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 |         |                        | 858.71 T                           |                                           |
| Average|        |                        | 49777.4 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

![Bar graph representation of Cobble generation before installation of Radiation Pyrometer](Image1)

![Bar graph representation of Cobble generation after installation of Radiation Pyrometer](Image2)

### iv. Analysis of Increased Production

**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.
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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