# Study & Calculation of Loss in Rail Length Occurred in the Bhilai Steel Plant Due to Scaling in the Furnace

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*Abstract*— Conventionally the production of rail track comprises of forming process in which rail is manufactured through rolling, during the process, semi-finished product i.e. bloom is recharged inside the furnace for several hours by using different types of mixed fuel gases. After getting the certain recrystallization temperature the bloom is passed by several passes and stages, to get an appropriate desired profile of rail section as per requirement. So basically in "Universal Rolling Mill" and "Rail & Structural Mill" of Bhilai Steel Plant there is some common issues related to Rail length during manufacturing process i.e. Shortage of length. This paper majorly focuses on the cause of scale loss during the production process & its effects on rail length. The methodology will describe about how process are carried out in order to collect data. Evaluation & outcome deals with the calculation & comparison of different parameters in both the unit of BSP. Finally, in the conclusion, methods are proposed for reducing the metal loss so as to get required rail length.

***Key words:*** Scale Loss, Scaling

## I. INTRODUCTION

### A. *Why Long Rails*

Concerns of safety and economy of operations have necessitated railroads the world over to switch to long rails with very few weld joints. The longer the length of the rail, the lesser the number of welds per kilometre length. The commuter enjoys a safe and bump-less ride and the railroad company saves on track life and maintenance. Bhilai Steel Plant has established long rail production facilities at a cost of Rs 1400 crore to cater to the demand for long rails from Indian Railways. Long rail complex produces rails up to 130 meter length and welded rail panels of up to 260 meter lengths, for ready use at site.

But BSP was unable to achieve this desired length of 130 meter rail in URM due to some losses. The main cause of such problem is mainly due to scale loss occurring inside the furnace which results in excess loss of steel as compared to the loss occurred in RSM unit of BSP.

## II. SCALE LOSS

Reheating furnaces consume approx. 70-80% of total energy consumption of rolling mill therefore it is paramount to monitor various furnace heat losses and execute necessary modifications to reduce them.

A survey for comparative analysis of various heat losses in reheating furnaces was conducted by BSP and it was found that major heat losses are through flue gas, furnace openings and doors(especially during bloom discharging) and excess scale formation.

The Disadvantages of scale formation include:

1) Steel loss representing a mass loss between 1 to 4.5 % of the slab depending on furnace operating conditions and slab thickness.
2) Scale pile-ups inside the furnace and slab transport path which requires a furnace shutdown period for cleaning.
3) Hindered heat transfer from the furnace environment the steel resulting longer heating cycles.

It is important then to minimize scale formation during reheating to a level to which it is advantageous. This, of course, requires a full investigation of all relevant parameters in the Operation of the furnace. However, because of the complexity of the process, i.e. industrial conditions, and time constraints, a thorough investigation of all parameters was not possible in the present work. The work was limited to the following:

1) Calculation of scale loss (steel loss) at both the furnace of the BSP.
2) Calculation of loss in length due to scale loss at both the unit.
3) Percentage scale loss at both the furnace.

In summary, the objective of this paper was to investigate scale formation of a bloom in an industrial steel reheat furnace. The aim was to gain knowledge on the important parameters affecting scale formation in practice & hence to control its formation to a level where it is advantageous.

### A. *Mechanism of Scale Loss*

The phenomena of scale formation (oxidation) on the steel surface during reheating of steel material in the reheating furnace are unavoidable and difficult to control. Disadvantages of scale formation include steel consumption and scale fall out in route to rolling mill, which requires clean up and usually cause environmental issues.

The mechanism for the high temperature oxidation of steel is given in Fig 1. The oxidation mechanism can depend on the transport of oxidant gas from the bulk gas phase, phase boundary reaction(s) at the gas/scale interface, or the diffusion of Fe cations to the scale/gas phase interface.

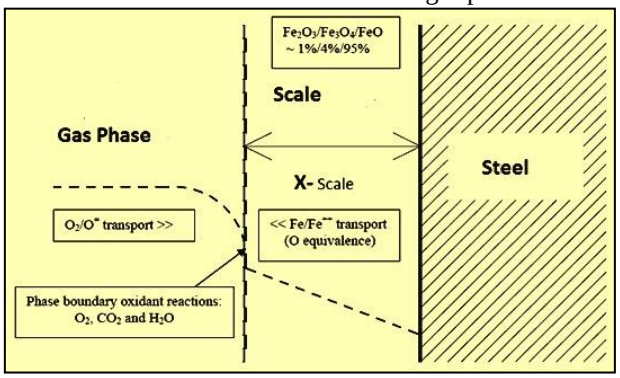



Fig 1. Mechanism for the High Temperature Oxidation of Steel

A saving of up to 35 % of steel lost to scale can be achieved by reducing the excess air in the furnace. Also, longer residence time and higher temperatures of the steel in

the furnace results in the formation of excessive amounts of scale.

There are normally two sources of $O_2$ in the reheating furnace. These are

1) Combustion air which is supplied to the burner for the combustion of the fuel, and
2) Air ingress which happens when there is a negative pressure in the furnace which is created due to various reasons and this leads to air ingress into the furnace atmosphere.

As air is used for combustion, excess oxygen also leads to formation of NOx emissions which causes nothing but the removal of heat through flue gases

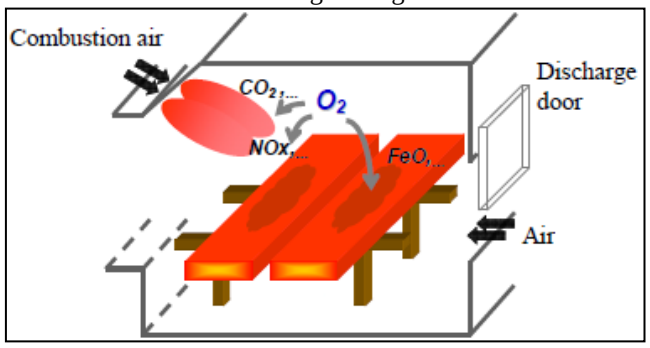



Fig. 2: Showing Formation of NOx Emissions

## III. Methodology

This analysis and study is based on the period of 3 month duration. The aim of this paper is to study & calculate the loss of steel in the form of scale formation which is taking place in the steel reheat furnace of URM & RSM Unit of BSP. The large number of parameters affecting this process requires tremendous amount of work in order to come up with the most practical procedure to observe, collect, record, analyse the data. The parameter directly influencing scale formation are slab temperature, in-furnace atmosphere ($CO_2$, $H_2O$, CO, $O_2$) steel grade and steel residence time in the furnace.

During the experiments, a large number of furnace operating data was monitored on-time. This data included bloom data (bloom dimensions & weight).

The bloom charging is systematic and is done in the following order.

1) The blooms are crane lifted and placed on charging pit.
2) Personnel then spray anti-cohesive solution of water, lime and white clay on the surface of the bloom.
3) The blooms are pushed from the pit to table, twos at a time.
4) The charging table is activated and the blooms are received at the pusher tables.
5) The pushers push the blooms into the furnace from the table one at a time. The pushed blooms enter into the furnace with one surface on the skids.

The pushed blooms enter into the furnace with one surface on the skids. These blooms are heated and soaked for at least 4 hours. After a span of 4 hours the blooms are discharged at the same rate as they are charged, i.e. one at a time. The discharge capacity of pusher furnace is 75T/hr end to end and the calorific value of gas supplied usually varies in a range of 1900 Kcal/m3 whereas The discharge capacity of URM furnace is 230T/H and the calorific value required is 2350 Kcal/m3 .The blooms are now collected by the de-scaling table wherein they are pushed into de-scales for scale removal. The process employs a pressurized jet of air and water to accomplish the task. Shortly after des-caling, a (relatively) small two high rolling mill called a scale breaker reduces the bloom's thickness by about one inch to break up any scale that remains. Just before the next reduction pass is taken, 'sweep sprays' clean away any loosened scale that remains on the slab surfaces.

The formation of scales during rolling is observed initially on the charged bloom due to chemical composition of the steel grade and hence the observation & data collection starts from measuring the bloom length and dimensional cross section.

A sample of 10 scales randomly was taken from both RSM & URM unit of BSP, & data are recorded. The instrument used in measuring the thickness of the scale is screw gauge the average thickness of scale in the RSM is 2.744 mm. The average thickness of scale in the URM is 6.94 mm.

To calculate the dimension of the blooms in both the RSM & URM unit of BSP, 15 samples of bloom in each unit of BSP was selected & measured with the help of measuring tape and their data are recorded. For calculating the total scale loss we have first determine the average weight of the bloom, & weights were measured using weighing machine.

- Average weight of the 15 bloom samples of RSM is 4466.77 kg &
- Average weight of the 15 bloom samples of URM is 8.32 tons.

After that rolling operation to be performed on the same sample blooms. After the rail comes out of the finishing passes we found the total rolled length with the help of software installed in RSM & URM unit. To calculate the weight of the rolled rail, we have considered the 60 kg rail profile, we have multiplied this 60 kg with the total rolled length of the rail to find out the total weight of the final rolled rail.

The total weight of the overall rolled rail length after rolling process in RSM is 4298.4445 kg. The total weight of the overall rolled rail length after rolling process in URM is 7.9493 Ton.

## IV. Evaluation & Outcomes

### A. Calculation of Scale Loss in RSM

The bloom weight is 4466.77 kg (approx.) i.e. 4.466 ton & the average dimension of the bloom is 300 x 340 x 5.67 m.

| S. No. | Bloom weight (kg) | Overall rail weight (kg) | Loss (kg) (Bloom weight – Overall rail weight) |
|---|---|---|---|
| 1. | 4501.59 | 4280.885 | 220.705 |
| 2. | 4418.9 | 4250.61 | 168.29 |
| 3. | 4455.89 | 4335.38 | 120.51 |
| 4. | 4523.92 | 4271.802 | 252.117 |
| 5. | 4455.53 | 4283.307 | 172.223 |
| 6. | 4454.83 | 4250.61 | 204.22 |
| 7. | 4446.11 | 4380.792 | 65.317 |
| 8. | 4449.72 | 4329.930 | 119.78 |

| | | | |
|---|---|---|---|
| 9. | 4470.33 | 4329.325 | 141.005 |
| 10. | 4440.63 | 4256.665 | 183.965 |
| 11. | 4484.03 | 4335.38 | 148.65 |
| 12. | 4451.39 | 4286.94 | 164.45 |
| 13. | 4448.84 | 4335.38 | 113.46 |
| 14. | 4476.05 | 4280.885 | 195.165 |
| 15. | 4523.92 | 4268.775 | 255.145 |
| Avg. | 4466.77 kg | 4298.445 kg | 168.325 kg |

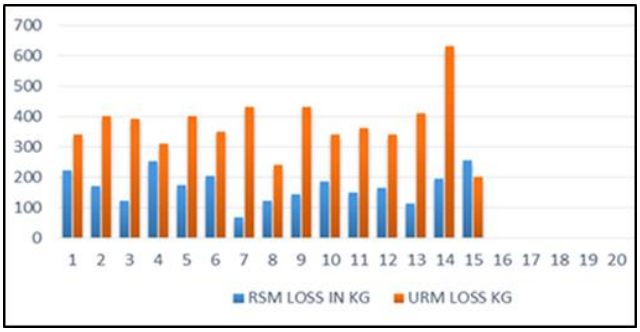
Table 1: Showing the Scale Loss (Steel Loss) in the RSM Unit

*B. Calculation of Scale Loss in URM*

The bloom weight is 8.3206 ton & the average dimension of the bloom is 10.748m. Comparing the bloom weight & the overall rolled rail weight of URM.

| S. No. | Bloom weight | Overall rail weight | Loss (kg) (Bloom weight – Overall rail weight) |
|---|---|---|---|
| 1. | 8.3 | 7.96 | 0.34 |
| 2. | 8.34 | 7.94 | 0.40 |
| 3. | 8.34 | 7.95 | 0.39 |
| 4. | 8.32 | 8.01 | 0.31 |
| 5. | 8.34 | 7.94 | 0.40 |
| 6. | 8.31 | 7.96 | 0.35 |
| 7. | 8.36 | 7.93 | 0.43 |
| 8. | 8.26 | 8.02 | 0.24 |
| 9. | 8.36 | 7.93 | 0.43 |
| 10. | 8.28 | 7.94 | 0.34 |
| 11. | 8.34 | 7.98 | 0.36 |
| 12. | 8.36 | 8.02 | 0.34 |
| 13. | 8.36 | 7.95 | 0.41 |
| 14. | 8.34 | 7.71 | 0.63 |
| 15. | 8.2 | 8 | 0.20 |
| Avg. | 8.320 Tons | 7.949 Ton | 0.371 Ton |

Table 2: Showing the Scale Loss (Steel Loss) in the URM Unit




Graph 1: Comparing the scale loss in both the plant

*1) Loss of Length in RSM*

The calculation of loss in length will give an idea about the actual rail loss due to scaling. So from above table the total scale loss in RSM is 168.325 kg. The weight per meter of rail 60.55 kg. So dividing this scale loss with weight per kg of rail will give the total amount of rail loss in RSM unit.

$$\text{loss of length} = \frac{\text{scale loss ( kg)}}{\text{weight of rail (per meter)}}$$
$$= \frac{168.325}{60.55}$$
$$= 2.78 \text{ meter}$$

*C. Percentage Scale Loss in RSM*

Calculation of the scale loss in the percentage will be easier to compare the loss in both the unit. Dividing the total scale loss by the average weight of bloom and multiplying it with 100 will give the required scale loss percentage.

$$\text{Percent scale loss in RSM} = \frac{\text{Total scale loss in RSM}}{\text{Average bloom weight of RSM}} \text{ X } 100$$
$$= \frac{168.325}{4466.77} \text{ X } 100$$
$$= 3.76\ \%$$

*D. Loss of Length in URM*

The calculation will give the loss of length in URM. So from above table the total scale loss in URM is 371 kg.

$$\text{loss of length} = \frac{\text{scale loss ( kg)}}{\text{weight of rail (per meter)}}$$
$$= \frac{371}{60.55}$$
$$= 6.12 \text{ meter}$$

So from above calculation, it is clear that the loss of length in URM unit is 6.12 meter.

*E. Percentage Scale Loss in URM*

Calculation of the scale loss in the percentage will be easier to compare the loss in both the unit. Dividing the total scale loss by the average weight of bloom and multiplying it with 100 will give the required scale loss percentage in URM.

$$\text{Percent scale loss in URM} = \frac{\text{Total scale loss in URM}}{\text{Average bloom weight of URM}} \text{ X } 100$$
$$= \frac{371}{8320} \text{ X } 100$$
$$= 4.46\ \%$$

So the percent scale loss in RSM is 4.46 %. It means that 4.46 percent of steel is wasted from 8320 Kg of bloom. So from the above result & discussion we can see that the percentage scale loss in URM is more as compared to the RSM. The below given table depict the scale thickness, scale loss, loss of length, percentage scale loss & gases used which gives a clear view of both the furnace.

| PARAMETERS | RSM |
|---|---|
| Scale Thickness | 2.744 mm |
| Scale loss | 168.325 Kg |
| Loss in Length | 2.78 m |
| Percentage scale loss | 3.76 % |
| Gases Used | CO Gas, BF Gas and LD Conv Gas |

Table 3: Comparing All the Data Calculated & Related to Both the Unit

*F. Discussing the Loss in Lengths*

As far the study that, RSM unit of BSP produces the smaller length rails i.e. 13m, 26m 52m & 65m, so there the scale loss doesn't affect the manufacturing of rail length & there is no such study about this losses before because RSM unit easily get the desired rail length even after so much wastage. The unit produces 71 metre approx. rolled length and the required length is 65meter (i.e. 13x5, 26x3, and 65x1). So let's say the scale loss occurred in RSM is 168.325 kg

Knowing that in 60 kg profile of rail the mass is 60.55 kg per meter approx. so it means we can save up to 2.78 meter of length by eliminating or controlling the scale loss, but this 2.78 meter will have no use because having already achieved the desired rail length of 65 meter and this extra 2.78 meter is somehow going to be in waste. So that's why scale loss doesn't affect much in the manufacturing of rails in RSM unit of BSP. Knowing that BSP is the sole producer of 130 meter rails, & in case of URM unit, the scale loss is more that is 371 kg as compared to RSM, As far the calculation the average length loss in URM unit is 6.94 meter & the average final rolled length is 129.626 meter approx. So if the scale loss is controlled in URM unit of BSP we can easily achieve the desired 130 meter length.

### *G. Discussing Scale Thickness in Both RSM & URM*

After the heating of bloom, the scale formation in terms of its thickness is measured by taking the average of the samples. From the below table it is clear that the thickness of the scale at URM is very high as compared to the scale thickness at RSM.

| | RSM | URM |
|---|---|---|
| Scale Thickness | 2.744 mm | 6.94 mm |

This variation in scale thickness is mainly due to the gas used in the URM. Due to non-availability of the BF gas & LD gas, only coke oven gas is supplied at the URM unit. But the problem is that the calorific value of the CO gas is very high i.e. 4200 to 4800Kcal/$m^3$ & the calorific value required inside the walking beam furnace is approx. 2350kcal/$m^3$, so in order to balance this calorific value excess of air is mixed with CO gas which in result leads to the more oxidation in the steel surface of bloom inside furnace.

## V. CONCLUSION

In the case of this research, dealing with a two reheat furnace i.e. pusher type & walking beam ,burners installed in different locations and a huge number of variables that were changing minute by minute, expectations of reasonable experiment repeatability were low. Having these thoughts in mind, the results obtained from this work were very consistent.

Consistent oxidation trends were obtained with excellent repeatability. On the other hand, this work has raised more questions than answers regarding the mechanisms of the observed effects and the reasons behind them.

1) Limited tables & results are available in the Literature on the oxidation of steel under conditions approximating those of the reheat furnace. The majority of the work described in this paper is limited to the oxidation of iron and steel under well-defined and constant conditions.
2) Longer residence times of steel in the furnace at higher temperatures resulted in the formation of excessive amounts of scale.
   This finding was of no surprise. It is well known that longer exposure at higher temperatures result in the formation of more scale. Therefore, if the samples are located in the intermediate or soak zone of the furnace, scale was seen to be forming in excessive amounts. The fact that when the scale is thicker, especially in these zones, this thickness has very little effect on the rate of scale growth, and suggesting that cracks and channels exist in the scale, through which the oxidising gases can penetrate. On the other hand, when the steel is positioned in zones of low temperature, such as preheat and charge zones, longer times at these zones had very little effect on the amount of scale formed.
3) Form the research, we came to know that the factors which are responsible for Scale formation. The scale formation mainly depend on three factors i.e.

a) Residual time
b) Temperature
c) Oxidising temperature.

Although the study in this research was not about the above listed factors but somehow it is related & provide a very base knowledge.

4) From the above observations, calculation, discussion and results it is clear that the scale loss occur in URM is 4.46% & in RSM is 3.76% of total weight of the bloom.

The reason we see is because of the gas used in the walking beam furnace is coke oven whose calorific value is approx. 4200 - 4700kcal/$m^3$. So to bring this high calorific value to desired value of 2450kcal/$m^3$ excess air is provided to maintain the stoichiometric ratio, Which result in excessive oxidising environment in the furnace. So if proper mixed gas is provided (like that in RSM pusher type furnace) the scale loss in URM will be controlled up to some extent where it will be advantageous.

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