Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 10; October, 2014 pp. 100-104

http://www.krishisanskriti.org/jbaer.html

Improving Energy Efficiency in Existing Reheating Furnaces of Small and Medium Sector Re-rolling Mills

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Abstract: **This paper describes various retrofitted schemes implemented by Research & Development Centre for Iron & Steel under the project sponsored by Petroleum Conservation Research Association, New Delhi to improve the performance of reheating furnaces of small sector Re-rolling mills. Implementation of various schemes resulted in reduction of specific fuel consumption by about 20% and improvement in furnace productivity by about 15%.**

Keywords: **Energy, Reheating furnace & Small re-rollers**

1. INTRODUCTION

Steel industry is an energy intensive industry and energy conservation is a major thrust area for sustainable growth for steel sectors in the present competitive business scenario and also to reduce environment pollution. There are about 1800 small and medium sector re-rolling mills in India and the rolling capacity of most of these mills is in the range of 5,000 - 50,000 tons/annum. Requirement of capital investment in these mills is low as many operations are carried out manually due to availability of cheap labour. However, energy consumption is very high due to primitive design of reheating furnaces and lack of knowledge for energy efficient operations.

Petroleum Conservation Research Association (PCRA), New Delhi sponsored a project to Research & Development Centre for Iron & Steel (RDCIS) of Steel Authority of India Ltd. (SAIL) to study and identify the barriers on energy conservation for reducing oil consumption and GHG emission in reheating furnaces (RHFs) of small and medium sector re-rollers. RDCIS developed the design, drawing and technical specifications alongwith cost estimation for a 7.5 t/hr capacity reheating furnace having all basic requirements to achieve better fuel efficiency, meeting the required demand of major re-rollers[1]. Small and medium scale entrepreneurs in India are not enthusiastic to invest money for constructing new energy efficient and scientifically designed furnaces. It is prudent to introduce energy efficient schemes in the existing furnaces of small re-rollers with minimum investment. Hence, PCRA sponsored another project to RDCIS for implementation of energy efficient technologies in two furnaces to reduce specific fuel consumption by bout 20 % and reduce the GHG emission by about 15 kg/t[2]. This project was completed in 2008. Later on, PCRA sponsored another project in 2012 to replicate the retrofitting technology for improving the energy efficiency in existing reheating furnace of small and medium sector re-rolling mills. The outcome of this project is described in following sections.

2. PRELIMINARY SURVEY OF SMALL RE-ROLLERS

About 80 RHFs of small re-rolling mills at Durgapur (West Bengal), Patna (Bihar), Jharsuguda (Odisha) and Raipur (Chhatisgarh) clusters were contacted for collecting their design and operational data with an aim to identify suitable schemes for implementation. Following observations were made after analysing these data:

- Producer gas (calorific value of 1000-1200 Kcal/ Nm^3) or pulverised coal is used as fuel by most of re-rollers.
- In general, furnaces are of capacity around 5 - 10 t/hr. However, new furnaces, which have come during last 4 – 5 years, are of higher capacity of 10 - 20 t/hr.
- Billet discharge temperature is higher (1250 – 1300^{0}C).
- Generally, mills are working for 10 –12 hours a day.
- Air preheat temperature is about 200^{0}C.
- Input materials are pencil ingots of 100mm x 125mm cross section. The finished products include strips, rods, angles, channels etc. of different sizes.
- Air/fuel ratio control is done manually.
- Flame impinges directly on the billets/ingots in most of the furnaces leading to localised heating. Even sticking of billets is observed due to melting of scale.
- Preheated oil and air pipes are not insulated properly.

- Specific fuel consumption in the furnaces varies from 100 to 150 kg/t (for coal / producer gas fired furnace) and 40 to 50 lit. /t (for liquid fuel fired furnace).

The trends of specific fuel consumption in RHFs of small re-rollers are presented in Table 1. [1, 2]

Table 1: Trends of specific fuel consumption in RHFs of small re-rollers in India

Specific fuel consumption (MJ/t)	RHFs of small re-rollers (%)
Below 1,500	10
1,501 – 2,100	28
2,101 – 2,500	55
Above 2,500	7

3. THERMAL ENGINEERING INVESTIGATIONS

Thermal engineering investigations were carried out in few selected RHFs to identify the areas requiring technological up gradation and operational improvements. During the preliminary survey it was observed that overheating of billets was one of the major causes for high heat consumption in furnaces. Hence, temperature profile of billets while being heated inside the furnace and their drop out temperatures at furnace discharge end were measured using thermovision camera. Since the mills were located very near to the furnaces, drop out temperature of 1280^0C for billets was felt to be very high. It is established that the scale formation can be reduced by 15 - 20% by reducing heating duration by 30 minutes and reducing temperature in soaking zone from 1275^0C to 1225^0C[3]. The thermal image of one over-heated billet at furnace discharge end was captured and presented in Figure 1. Flue gas analysis at the charging end of furnace was also conducted to assess the quality of combustion by measuring CO and O_2 using portable flue gas analyser.

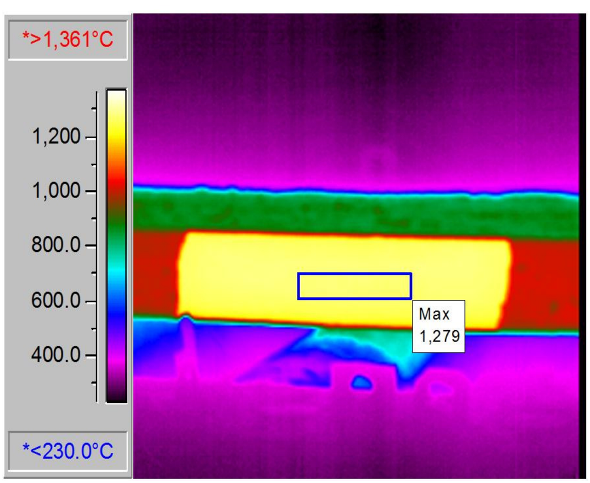

Fig. 1: Temperature profile of billet

4. SCHEMES FOR EXISTING REHEATING FURNACES

Based on thermal engineering investigations carried out in existing RHFs, potential energy consumption schemes were incorporated in one of RHF of small and medium scale re-rollers:

- Improvement in design of burners
- Improved insulation for pre-heating zone and pipelines
- Augmentation in instrumentation facilities
- Improvement in life of furnace hearth

4.1 Improvement in design of burners

Producer gas (PG) having calorific value of about 5,000 KJ/Nm^3 is used as an alternative fuel due to higher cost of liquid fuel. The performance of the existing PG burners was not satisfactory. The design of the existing PG gas burner was of tube-in-tube type. The flames generated by these burners were lazy and dull indicating incomplete combustion. Considering the availability of low PG pressure (about 50 mmWC) and high combustion air pressure (700-800 mmWC), air swirler with swirl angle of 15^0 was provided in the path of combustion air. Thus, an efficient PG burner (Figure 2) was designed & developed by RDCIS and installed in the reheating furnace [4]. The burners were relocated and their orientations were changed to avoid direct flame impingement on the billets. The photograph of producer gas burner installed is shown in Fig.3.

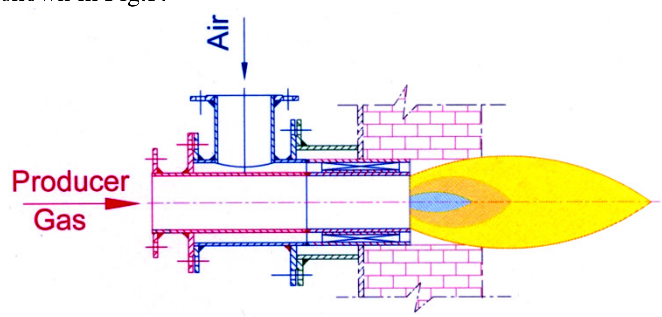

Fig. 2: Producer gas burner

Fig. 3: Producer gas burner installed in soaking zone of furnace

4.2 Improved insulation for pre-heating zone and pipelines

Ceramic fibre module having low thermal mass and heat resistant properties was used for insulating the sidewall and roof of the extended zone to avoid heat loss during heating and cooling of furnace due to intermittent operation. The insulation of pipeline of double pass recuperator is shown in Fig. 4.

Fig. 4: Insulation of pipeline of recuperator

4.3 Augmentation in instrumentation facilities

It was observed during study that most of the furnaces were not provided with the basic instrumentation facilities like measurement of zonal temperature, flow rates of fuel and combustion air. Thermocouple protecting ceramic sheath used to get damaged frequently (2-3 weeks) due to thermal shock because of only 12 - 14 hours of furnace operation in a day. Thermocouples with chromel alumel (K-type) element for heating zone & Pt/Pt-Rh (S-type) element for soaking zone having ceramic sheath with better spalling property were installed. An orifice plate and U-tube manometer were installed to measure combustion air flow rate. Further, temperature gauges for measuring flue gas temperatures before & after recuperator and air preheat temperature were also installed.

4.4 Improvement in life of furnace hearth

Life of existing RHF was about 5-6 months only with conventional refractory bricks. Hence, Ultra Low Cement Castable (ULCC) was introduced to improve the life of solid hearth in soaking zone to 2 years

5. EXPERIMENTAL

The above schemes were incorporated in the reheating furnaces of small re-roller at Jharsuguda. Detailed thermal engineering investigations were carried out to assess the thermal profile of billets inside the furnace. Further, combustion efficiency and operating parameters were measured. Production and fuel consumption data were also compiled. Based on these data, heat balance calculation was made.

5.1 Billet heating inside the furnace

Two holes of 11 mm diameter, first hole upto core and second hole upto 10 mm above the bottom of test billet, were drilled as shown in Figure 5 to know the rate of heating of billets while travelling inside the RHF. Test billet was charged inside the RHF. Temperature of test billet was measured by inserting thermocouples into the holes through inspection windows on one side refractory wall of furnace. Soaking zone temperature and heating zone temperature were maintained at about 1220^0C and 1150^0C respectively. The temperatures profile of test billet during its travel is presented in Figure 6.

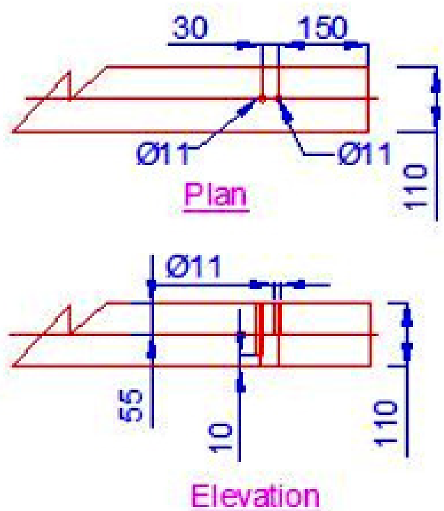

Fig. 5: Size & location of holes in test billet

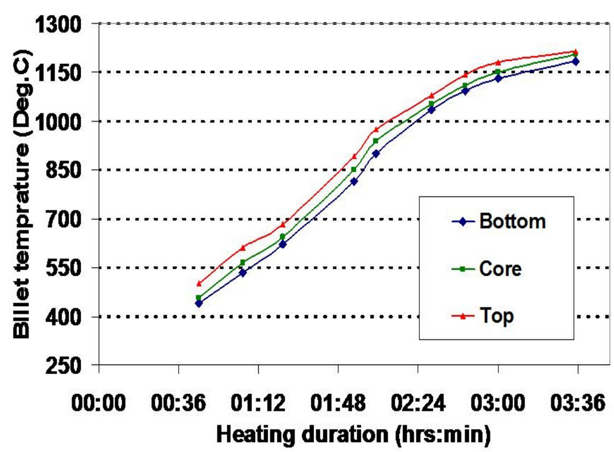

Fig. 6: Temperature profile of test billet

5.2 Flue gas analysis

Flue gas analysis was carried out at charging end of the furnace (before recuperator) to know the quality of combustion. Percentage of CO and O_2 were measured using portable gas analyser and are presented in Table 2.

Table 2: Flue gas analysis before & after implementation

Sl. No.	Before implementation		After implementation	
	O_2 (%)	CO (ppm)	O_2 (%)	CO (ppm)
1	6.0 – 6.5	0	3.6 – 4.0	0
2	6.8 – 7.0	0	3.0 – 3.2	0
3	6.5 – 6.9	0	3.1 – 3.3	0

5.3 Production & Specific Fuel Consumption

The operational data of the reheating furnace and production & specific fuel (coal) consumption data before and after implementation of retrofitting schemes were collected and the same are presented in Table 3 and Table 4 respectively.

Table 3: Operational data of the furnace before & after implementation

Stage	Average temperature (^{0}C)			
	Soaking zone	Heating zone	Flue gas	Pre-heated air
Before	1250	1100	700	375
After	1220	1150	650	425

Table 4: Production and specific fuel data of the furnace before & after implementation

Stage	Production (t/hr)	Specific fuel (coal) consumption (MJ/t)
Before	13	2746
After	15	2089

5.4 Heat Balance

Heat balance has been calculated before and after implementing different schemes based on the operational data given in Table 3 and the same is presented in Table 5.

6. RESULTS & DISCUSSIONS

It can be seen from Table-3 that soaking zone temperature of 1250^{0}C before implementation of various schemes is on higher side considering the mill located very close to the furnace. The temperature profile of billet (Figure 6) indicates that drop out temperature of billet has been reduced to 1215^{0}C after implementing various schemes leading to reduced probability of sticking of billets due to overheating. It can be observed that the core & bottom temperature of billets are 1205^{0}C and 1185^{0}C respectively after 3 hr. 35 min. indicating proper heating of billets. Table 2 indicates that furnace performance has improved after installation of PG burners. Flue gas analysis shows that the O_2 content has decreased from 6.0–7.0 % to 3.0–4.0 %. It is very important to maintain oxygen level at about 2% and reduce soaking zone temperature in order to minimise the scale formation and specific fuel consumption. Also, furnace temperature is to be brought down below 1000^{0}C during long delays.

Table 5: Heat balance for reheating furnace of small Re-roller

Parameters	Heat Content (MJ/t)	
Input	Before implementation	After implementation
Fuel (Producer gas from coal)	2453	1700
Sensible heat of fuel	339	234
Sensible heat of combustion air	330	218
Output		
Stock (steel)	602	586
Flue gas	1034	586
Radiation and other un-accounted losses	1486	980

Table 3 indicates that average air preheat temperature has increased from 375^{0}C to 425^{0}C and flue gas temperature has reduced from 700^{0}C to 650^{0}C. It can be seen from Table 4 that the specific fuel (coal) consumption has reduced by about 24 % from 2746 to 2089 MJ/t. Further, the productivity of furnace has increased from 13 to 15 t/hr (by about 15%) due to reduced residence time of billets inside the furnace. The main reasons for reduction in specific fuel consumption are improvement in design of producer gas burners and reduced residence time of billets inside the furnace.

Table 5 indicates that flue gas loss has reduced by about 43 % from 1034 to 586 MJ/t due to reduced Oxygen content in flue gas. Further, it can be seen from Table 5 that radiation & other unaccounted losses has reduced by 34 % by introducing ceramic fibre module in the roof & sidewalls of preheating zone and side walls of heating zone leading to reduced furnace shell temperature.

The hearth life of soaking zone is expected to improve significantly from 5-6 months to about 2 years after replacing conventional bricks (super duty alumna bricks) by Ultra Low Cement Castable (ULCC). Thus, partial repair of soaking zone hearth can be done once in a year with changed ULCC blocks against the earlier repair in 5-6 months resulting in better availability of furnace. Further, thermocouple life has increased significantly from 2-3 weeks to more than a year due to better ceramic sheath material having good spalling characteristic. This would help in maintaining optimum temperature regimes.

7. CONCLUSIONS

The various energy efficient schemes identified and implemented in two reheating furnaces of small Re-rollers have reduced the specific fuel (coal) consumption by about 24 % along with increase in furnace productivity by about 15% and have shown good financial benefit with payback period of less than 6 months. The furnaces with implementation of various schemes are in regular operation and their performance is quite satisfactory.

8. ACKNOWLEDGEMENT

Authors are grateful to the management of RDCIS, SAIL Ranchi and PCRA, New Delhi for providing the opportunity and necessary guidance to complete the above project. We are also thankful to the entrepreneurs of small and medium sector re-rollers for assisting and allowing the implementation of various schemes in their furnaces. We also wish to thank our management for according permission to present the paper in this conference.

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