Recent Research in Science and Technology 2013, 5(5): 33-36
ISSN: 2076-5061
Available Online: http://recent-science.com/

# Assessment of energy efficiency in reheating furnace of a steel plant by using process heating assessment and survey tool (PHAST)

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**Abstract**

Steel is one of the most common materials that we come into contact in our day to day life. The steel industry is the major energy intensive industry among all industries, which emits large amount of greenhouse gases (GHG). These GHG carry energy in the form of heat along with them, have very harmful impact on the environment as well as result in direct economical loss for the industry. The present study assesses energy efficiency in a steel manufacturing company, namely Jayasawal's NECO Industries Ltd. at Siltara Raipur, with the help of process heating assessment and survey tool (PHAST). Overall efficiency determined in the reheat furnace was 44.66%. Flue gas losses were the biggest energy losses in the reheat furnace, accounting for 40.2% of the total energy losses during full production.

**Keywords:** Energy efficiency, waste energy recovery, GHG, PHAST, steel.

## INTRODUCTION

Steel is one of the most common materials that we come into contact in our day to day life. The iron and steel sector is the highly energy intensive sector all over the world. The *Manufacturing Energy Consumption Survey, 2002*, a survey done by the U.S. Department of Energy (Energy Information Administration), shows that the iron and steel sector is the third largest energy consuming sector. Improving energy efficiency is the most cost effective way to reduce energy consumption and increase production. Less wastage of heat of all industries, including the steel industry, will reduce concentration of green house gases [GHG] into the environment.

The present study evaluates the energy assessment of process heating operation of steel in the reheating furnace at Jayaswal's NECO Industries Limited (JNIL), Siltara, Raipur, (C.G) by using process heating and assessment survey tool (PHAST). JNIL is an integrated Steel Plant with manufacturing capacity of 400,000 TPA steel.

PHAST was developed by the U.S. Department of Energy. Industries can survey all heating equipments that consume steam, electricity, or fuel gas by the use of this tool and identify the energy losses and energy efficiency potential.

The study includes the energy assessment to get the energy efficiency of the reheating furnace by calculating the following losses:

**Wall losses:** Wall or transmission losses are caused by the conduction of heat through the walls, roof, and floor of the heating device.

**Cooling media losses**: Cooling protects rolls, bearings, and doors in hot furnace environments, but at the cost of lost energy. These components and their cooling media (water, air, etc.) become the conduit for additional heat losses from the furnace.

**Radiation (opening) losses:** Furnaces and ovens operating at temperatures above 1,000°F might have significant radiation losses. Hot surfaces radiate energy to nearby colder surfaces, and the rate of heat transfer increases with the fourth power of the surface's absolute temperature.

**Flue gas loss:** Waste-gas loss, also known as flue gas or stack loss is made up of the heat that cannot be removed from the combustion gases inside the furnace. The reason is heat flows from the higher temperature (source) to the lower temperature (heat receiver).

**Air infiltration:** Excess air does not necessarily enter the furnace as part of the combustion air supply. It can also infiltrate from the surrounding room if there is a negative pressure in the furnace. Because of the draft effect of hot furnace stacks, negative pressures are fairly common, and cold air slips past leaky door seals and other openings in the furnace.

The rate and amount of heat losses in each category could be calculated by providing following inputs:

**Water losses**: water flow rate, temperature difference between water in and out, etc.

**Wall, hearth and roof losses**: outside area of furnace, thickness and thermal properties of refractory and insulation, surface temperature, etc.

**Opening losses**: area of opening and by furnace inside temperature.

**Flue gas losses**: flue gas temperature, combustion air temperature and oxygen in flue gas.

**Atmospheric losses**: temperature difference between in and out atmosphere and atmosphere flow rate.

## METHODS

The energy assessment of the reheating furnace was done by the use of PHAST (Process heating and survey tool). During the assessment period semi-finished billets were used for heating in the reheating furnace.

## Data collection

**Step 1:** Measurement of structural data for reheat furnace including its dimensions, layer information, opening areas and wall information.

**Step 2:** Collection of production data on the dates February 18th 2012, March 27th 2012 and April 18th 2012 including flue gas temperature, waste gas temperature, furnace temperature, and water temperature, discharge temperature, inside temperature and opening cycle and time of charge and discharge ends. The temperatures for different variables were read every 5 min and averaged over the three days for this analysis. The collected data are as follows:

Table 1

| Parameter | Current | Modified |
|---|---|---|
| Feed rate (kg/h) | 50000 | 50000 |
| Furnace inside temperature(◦C) | 1275 | 1170 |
| Wall surface temperature(◦C) | 224.67 | 178.5 |
| Roof and hearth temperature(◦C) | 225 | 200 |
| Combustion air temperature(◦C) | 45 | 104 |
| Flue gas temperature(◦C) | 620 | 600 |
| % oxygen in flue gas | 6.5 | 4.5 |

## Energy assessment

The energy assessment of the reheating furnace was done by calculating the energy efficiency and energy losses by feeding the appropriate data in the furnace analysis portal of software tool PHAST.

## RESULT

The reheating furnace was 24.0 m long, 1.5 m high and 10.5 m wide in size with 18 fuel fired burners. Blast Furnace Gas with heating value of 0.0343 GJ/Nm$^3$ was being used as fuel. There were 6 peep holes and an opening for pusher and discharge end each having a dimension of 500mm × 500mm. These openings were considered as fixed opening at the furnace wall. There was a curtain at the feed/charge end which was having dimensions 9.5m × 750mm.

## Energy losses in the reheat furnace:

The energy losses calculated by the PHAST is tabulated as follows:

| S.N. | Area of heat consumption | | Heat losses (kJ/hr) |
|---|---|---|---|
| 1. | Furnace load/charge material | | 40,137,500 |
| 2. | Flue gas | | 36,797,836 |
| 3. | Other | | 7,333,918 |
| 4. | Wall | | 1,516,897 |
| 5. | Opening | Fixed | 323,672 |
| | | Variable | 1,022,815 |
| 6. | Atmospheric | | 1,410,601 |

## Furnace Summary

## Snaky diagram

The result given by PHAST is in the form of “Static Snaky” diagram as shown in the figure below. The values shown against each arrow is representing the category of heat losses or heat contents.

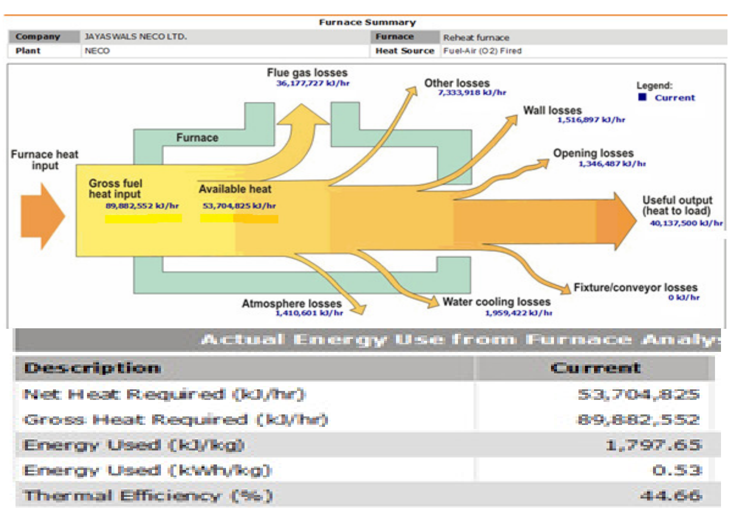



Fig. Snaky diagram

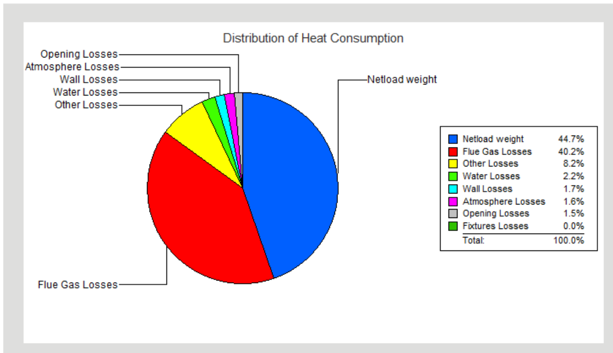
### Pie diagram

The diagram is showing the values of the heat content for each category. The result given by PHAST under the furnace analysis section is in the form of "Pie" diagram as shown in the figure below. The values shown are the distribution of gross heat consumption by the operation. These values are in percentage of different categories of the losses for the current and the modified conditions separately.

**Furnace Analysis**

| | | | |
|---|---|---|---|
| Company | JAYASWALS NECO LTD. | Furnace | Reheat furnace |
| Plant | NECO | Heat Source | Fuel-Air (O2) Fired |

Current Condition Heat Consumption (kJ/hr)    Gross Heat Consumption Data




**Heat Storage (kJ) : 518,932,069**    **Thermal Efficiency (%) : 44.66**

| Area of Heat Consumption | kJ/hr |
|---|---|
| Netload weight | 40,137,500 |
| Flue Gas Losses | 36,177,727 |
| Other Losses | 7,333,918 |
| Water Losses | 1,959,422 |
| Wall Losses | 1,516,897 |
| Atmosphere Losses | 1,410,601 |
| Opening Losses | 1,346,487 |
| Fixtures Losses | 0 |
| **Total** | **89,882,552** |

Fig. Pie diagram

The energy efficiency reported by PHAST was 44.66. The flue gases loss is reported to be 40.2%, which is the largest among all accounted losses during the operation. As JNIL does not have any fixture, basket or tray for materials handling, so there are no material handling losses in the reheat furnace.

## DISCUSSION

This assessment of energy found the following areas of efficiency improvement

### Waste heat recovery

The flue gases coming out from the reheating furnace contain substantive amount of heat energy which can be reused as.

### Load Preheating

The billets are loaded in the furnace at ambient temperature, so heat is required for initial heating of that billets. This heat requirement can be fulfilled by the sensible heat going out of the stack along with flue gases

### Preheating Combustion Air

Combustion air can be preheated in the recuperators by using heat from waste gases from the furnace. This reduces fuel consumption, increases flame temperature and improves furnace efficiency.

### Proper maintenance of the furnace

As observed at JNIL there is lack of maintenance inside the furnace. At the shut down period there are too many cracks and erosions observed on the refractory lining made by 60% alumina brick(fire clay bricks) at the inside wall of the furnace. To overcome losses due to the lack of maintenance the 90% high alumina castable can be used to fill the cracks so that heat transfer must be resisted from inside to the outside wall of the furnace.

### Proper utilization of Control system

In the reheating process, furnace pressure and temperature control have significant effects on energy efficiency improvement. The negative pressure inside a reheat furnace can cause ambient air to enter into the reheat furnace, which needs extra energy to heat the leakage air to flue gas temperature. Furnace pressure controller can keep a positive pressure in the furnace chamber to reduce atmosphere losses.

**Upgrading the charge end opening**

The charge end is having provision of mechanical operated curtain, which is in the current situation 100% opened. The provision was so made that the curtain was open at the time of charging only.

**Maximizing the furnace capacity**

The furnace should run on the full capacity i.e. 100% load as the efficiency is directly proportional to the load charged.

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