Analysis of Reheating Furnaces in Steel Plant

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Abstract:

The aim of this paper is to analyze the Recuperative Burner and Regenerative Burner for various types of reheating furnaces in steel plant. A survey is done on various furnace used in steel plant and such Equipment has been designed and installed in order to achieve optimization in reheating process. The flue gases temperatures of the burners are determined to suit with the sizes of the reheating furnaces by considering the air temperature, the fuel cost and the investment cost. As per considerations, the Regenerative Burner is more suitable in steels plants and better life span.

Keywords :
Energy Balance, Recuperative Burner, Regenerative Burner, Reheating Furnace.

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1) Introduction:

Today's burning question for the human race that how to transfer the dependency on the fossil fuel into renewable environment friendly sources. At the present time, the fuel cost has increased highly which affected the production cost of the steel. the average energy costs of steel industry are about 15% - 30% of the production cost. Now the main focus of manufacturing industry is on increasing energy efficiency of their production processes. The fuel is used in the reheating furnace to heat the billet or the slab in the rolling process. In Thailand, the waste heat is recovered to preheat the combustion air by using the recuperator, the air preheater, the waste heat boiler, the economizer, and the high efficiency burner. The steel industry is currently using the recuperator, which can preheat the temperature of the combustion air upto 300° C and the efficiency is nearly 30%. The high efficiency burner is the new approach to save the energy used in the reheating furnaces, which have the exhaust gas at high temperature during the burning process of steel. The high efficiency burner is proposed instead of the recuperator and the conventional burner. It can preheat the temperature of the combustion air about 600° C to 800°C and the efficiency can increase up to 90% with the energy saving of 10% to 20%.

2) Introduction to Regenerative Burner and Recuperative Burner:

The structure of the recuperative burner is same as that of radiation heat exchanger tube which heats the inlet air up to the higher temperature about 750° C by recovering the heat from the exhaust gas to the inlet air. Hence, the exchanged heat in the burner can improve the combustion efficiency and save the fuel cost approximately 25% to 30%.

A regenerative burner is a combustion heating system allowing extremely high-efficient recovery of exhaust heat in the industrial furnace by transferring the heat from exhaust gas to inlet air that will be used in the combustion. Owing to its great reduction effect of fuel efficiency, this system has been specifically adopted and popularized in relatively high temperature furnaces, including heating furnaces for rolling, forging furnaces, heat treatment furnaces, melting furnaces, baking furnaces, and deodorizing furnaces, as a superb means for saving cost energy and reducing CO_2.(http://www.osakagas.co.jp)

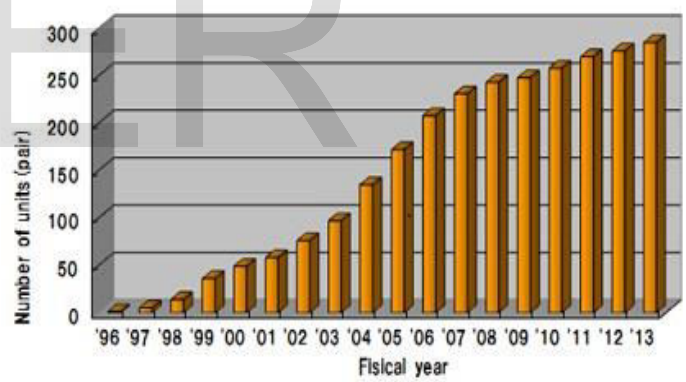

Figure 1: Number of accumulated sales units of Osaka gas regenerative burner

3) Principle of Regenerative Burner and Recuperative Burner:

Regenerative burner system generally ignites a pair of burners integrated with the heat reservoirs alternately at intervals of several tens of seconds. While one burner is burning, the exhaust gas passes through and heats the other burner's heat reservoir to recover the energy of the exhaust gas.

Then, when the other burner burns, the air for combustion in turn passes through the preheated heat reservoir to recover the exhaust gas energy which had conventionally been wasted, to provide high efficient combustion.

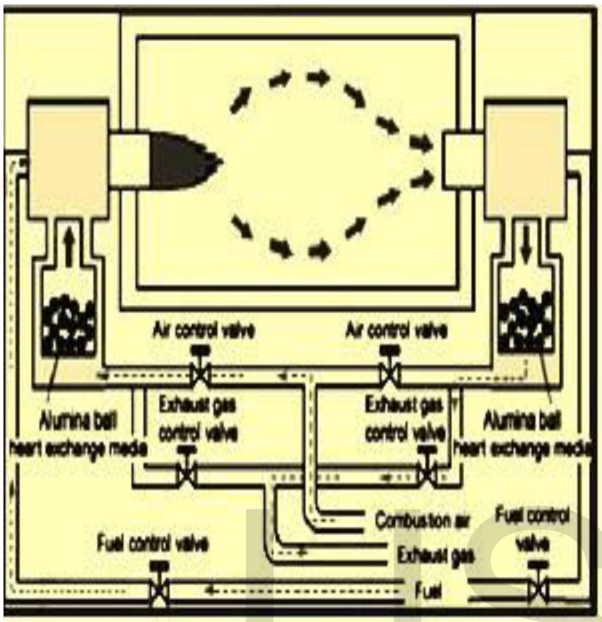

Figure 2: Principle of Regenerative Burner system

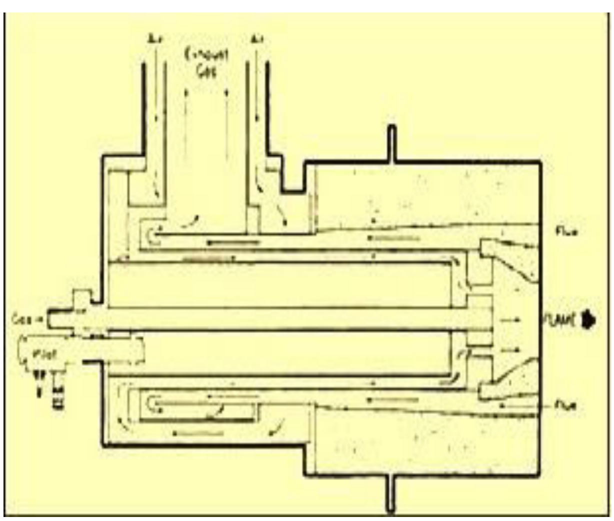

Figure 3: Principle of Recuperative Burner System

4) Constructional View Of Furnace:

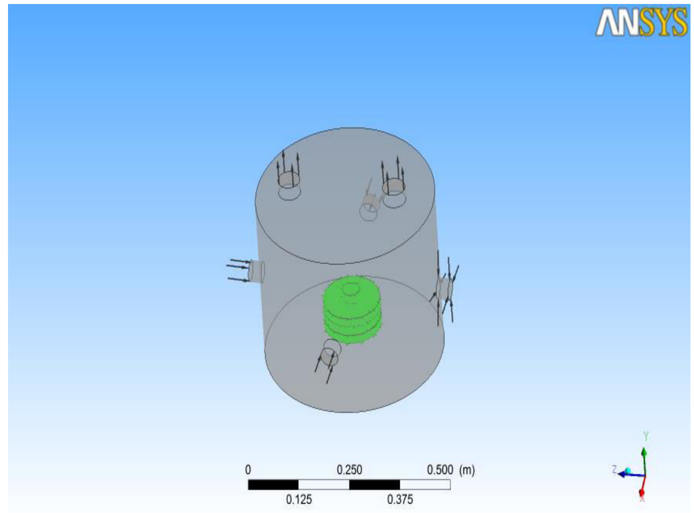

Figure 4: Constructional View of Furnace

The above figure depicts the constructional view of furnace with a billet placed inside it. Flue gases enter from the side nozzle of furnace and heat up the billet. After heating billet flue gases come out the nozzle placed at top.

5) Analysis of Turbulence Eddy Dissipation:

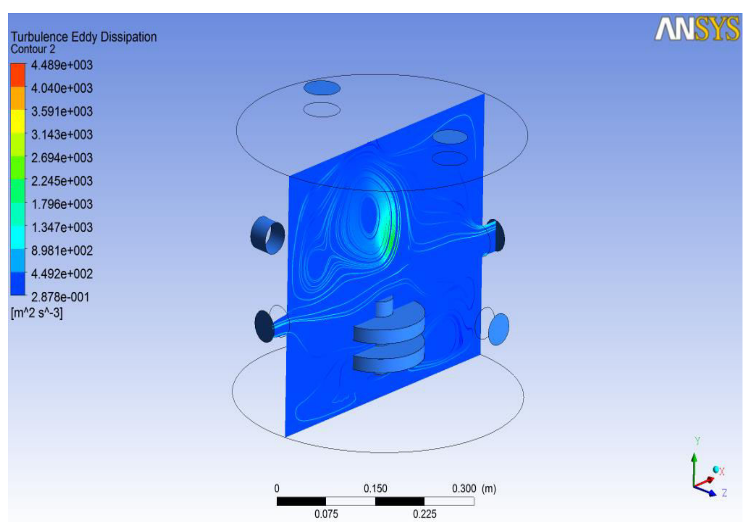

Figure 5: Turbulence Eddy Dissipation

From the above figure we seen that as flue gases enter the furnace they follow the eddy path as shown in above analysis. The above color coding shows the turbulence eddy dissipation at different points.

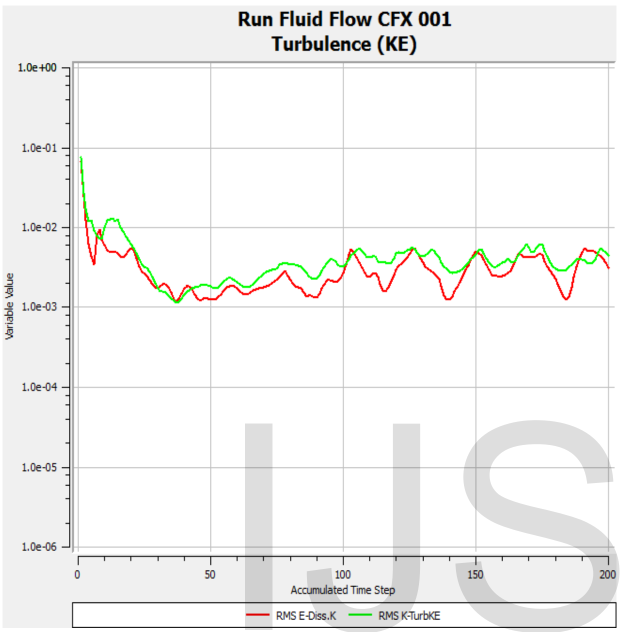

Figure 6: Graphical Representation of Turbulence

6) Velocity Analysis of Furnace:

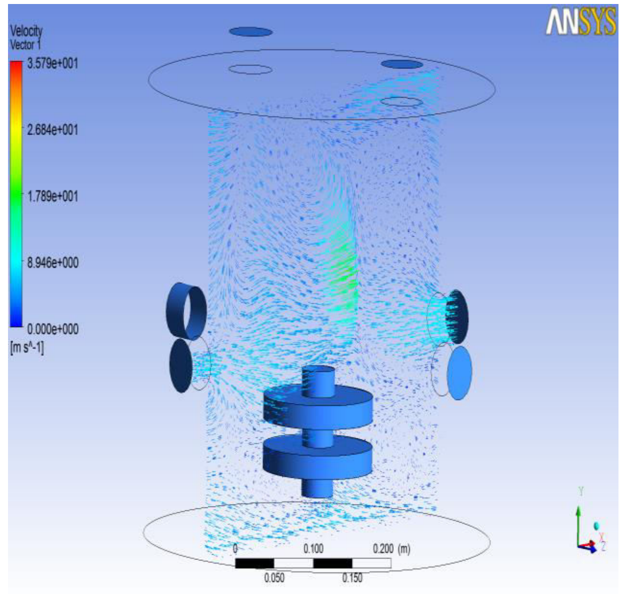

Figure 7: Showing Velocity in Furnace

The above figure depicts the velocity of flue gases at different point entering in the furnace from the nozzle.

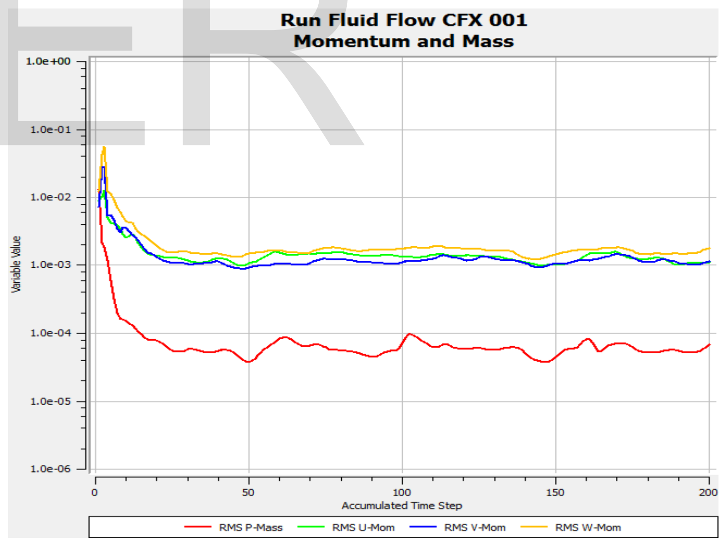

Figure 8: Graphical view of momentum and mass

7) Temperature Analysis For Billet:

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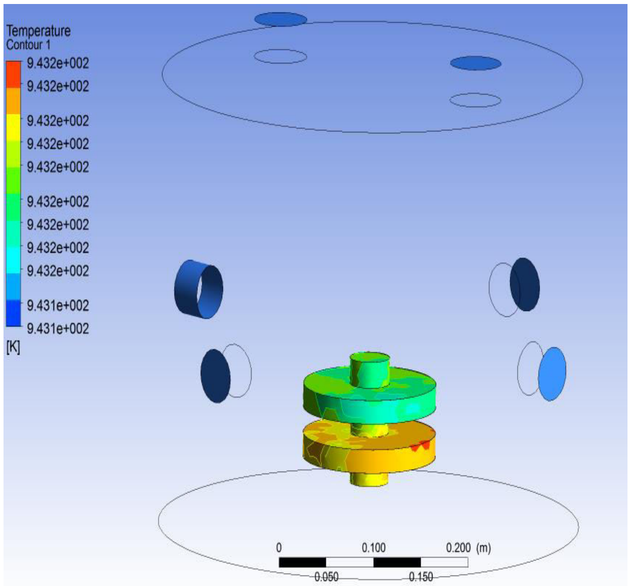

Figure 9: Temperature Analysis for Billet

This figure indicates the different temperature value at various point of billet. from the above analysis we concluded that upper portion of billet has low temperature than the lower portion of the billet.

8) Temperature Analysis in Furnace:

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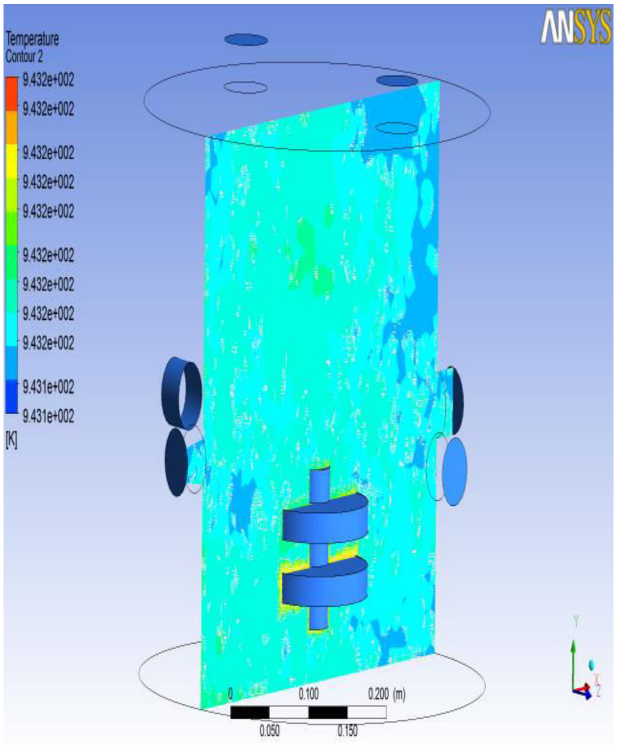


Figure 10: Temperature Analysis

The above shows the inside temperature of furnace at its different points.

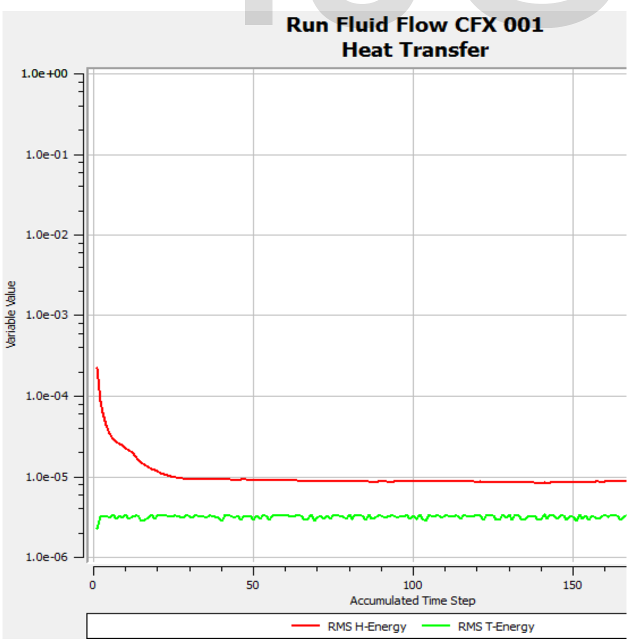


Figure 11: Graphical representation of heat transfer

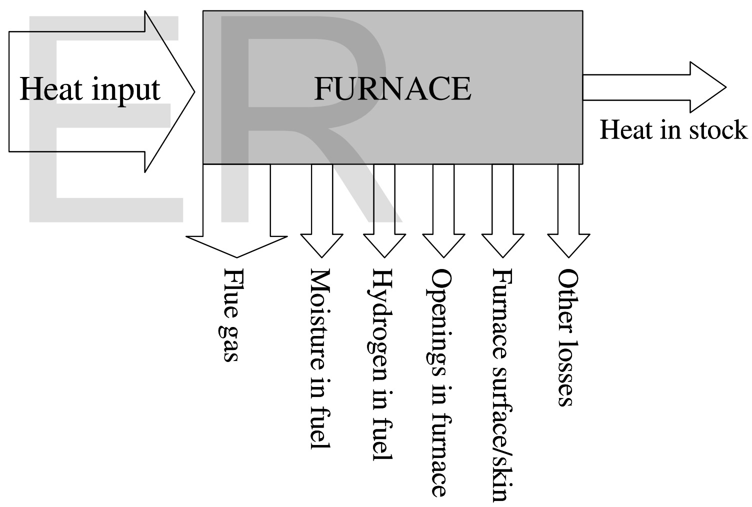
9) Heat Losses Affecting Furnace Performance:

All heat added to the furnaces should be used to heat the slab or stock. In practice, however, a lot of heat is lost in several ways as shown in the figure.

Figure 12: Heat losses in walking Beam Furnace

The furnace heat losses include:

- **Flue gas losses:** Part of the heat remains in the combustion gases inside the furnace. This loss is also called waste-gas loss or stack loss.



- **Loss from moisture in fuel:** Fuel usually contains some moisture and some of the heat is used to evaporate the moisture inside the furnace.
- **Loss due to hydrogen in fuel:** which results in the formation of water
- **Loss through openings in the furnace:** radiation loss occurs when there are openings in the furnace enclosure and these losses can be significant, especially for furnaces

operating at temperatures above 600°C. A second loss is through air infiltration because the draft of furnace chimneys cause a negative pressure inside the furnace, drawing in air through leaks or cracks or whenever the furnace doors are opened.

- **Furnace skin / surface losses,** also called wall losses: while temperatures inside the furnace are high, heat is conducted through the roof, floor and walls and emitted to the ambient air once it reaches the furnace skin or surface.
- **Other losses***:* there are several other ways in which heat is lost from a furnace, although quantifying these is often difficult, for example, losses due to formation of scales.

10) Efficiency of Furnace:

A furnace's efficiency increases when the percentage of heat that is transferred to the stock inside the furnace increases. The efficiency of the furnace can be calculated in two ways:

- **Direct method**
- **Indirect Method**

Direct method:

- The efficiency of a furnace can be determined by measuring the amount heat absorbed by the stock and dividing this by the total amount of fuel consumed.
- Thermal efficiency of the furnace =Heat in the stock / Heat in the fuel consumed for heating the stock
- The quantity of heat (Q) that will be transferred to stock can be calculated with this equation:

$$Q = m \times C_p (t1 - t2)$$

Where,

Q = Quantity of heat of stock in kCal

m = Weight of the stock in kg

Cp= Mean specific heat of stock in kCal/kg oC

t1 = Final temperature of stock in oC

t2 = Initial temperature of the stock before it enters the furnace in °C

The heat input is 400 liters per hour. The specific gravity of fuel is used to convert this into kg. Therefore: 400 l/hr x 0.92 kg/l = 368 kg/hr

The heat output is calculated as follows:

= m x Cp x ΔT

= 6000 kg x 0.12 x (1340 – 40)

= 936000 k Cal

The efficiency is:

= (heat input / heat output) x 100

= [(936000 / (368 x 10000)] x 100 = 25.43 percent

The approximate heat loss is 100% – 25% = 75%

- The furnace efficiency can also be determined through the indirect method, similar to the evaluation of boiler efficiency. The principle is simple: the heat losses are subtracted from the heat supplied to the furnace. ***(Note that a detailed methodology to calculate each***

individual heat loss is provided in the chapter)

- Adding the losses a to f up gives the total losses:
  - Flue gas loss = 57.29 %
  - Loss due to moisture in fuel = 1.36 %
  - Loss due to $H2$ in fuel = 9.13 %
  - Loss due to openings in furnace = 5.56 %
  - Loss through furnace skin = 2.64 %
  - Total losses = 75.98 %

The furnace efficiency calculated through the indirect method = 100 – 75.98 = 24.02%

11) Conclusion:

The suitable preheating air temperatures of two burners for 3 plants are investigated for the reheating furnaces in Thailand. It is found that the regenerative burner can save the energy more than the recuperative burner at the preheating air temperature at 900°C, which is suitable for all reheating furnace capacities based on the considerations of the net present value for the project time of 60 years and the shorter payback periods. The sensitivity analysis is also discussed for all factors which are not affected the NPV of the project. It is understood that the investment of the high efficiency burner is required to save the energy used in the reheating furnace. Hence, it is an alternative way to install the regenerative burner in the reheating furnace for the steel industry to save the energy cost.

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