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Effect of Combustion Air Pre-Heating In Carbon Monoxide Emission in Diesel Fired Heat Treatment Furnace

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ABSTRACT
This paper describes the effect of combustion air pre- heating in Diesel fired heat Treatment Furnace. The main heat treatment processes are Normalizing, Tempering, Hardening, Annealing, Solution Annealing and Stress Relieving. The emission of carbon monoxide is measured with combustion air pre-heating and without pre-heating. The results are then compared and it is found that the emission of CO is reduced by 29.12%. With the Combustion air pre-heating a considerable reduction in Specific Furnace Fuel Consumption (SFFC) is obtained. The test was caaried out at Peekay Steels Casting (P) ltd, Nallalam, Calicut.
General Terms: Heat Treatment Furnace
Keywords: SFFC, Pre- heating, Combustion,Emission

I. INTRODUCTION

Heat treatment is a process on metals or alloys to cause relief of internal stress, harden or strengthen metals, improve machinability, change grain size etc... Different types heat treatment process are Annealing, Normalizing, Hardening, Tempering etc.. It involves heating and cooling of metals or alloys at different rates depending up on requirements. In the company Peekay Steels there are three diesel fired furnaces, four LPG fired furnace of which one is idle and one is under construction and one electric furnace. The capacities of three different diesel fired furnaces are 7 ton, 10 ton and 13 ton. The objective of the project is to improve the thermal efficiency of a diesel fired heat treatment furnace and to reduce diesel consumption by some experimental investigations. Here for the sake of furnace a new term (SFFC) Specific Furnace Fuel Consumption is introduced. It is the amount of diesel consumed per unit tonnage of material processed in the furnace and per hour of furnace operation. Our objective is to reduce SFFC or increase thermal or furnace efficiency. Thermal efficiency improvement is done by reducing diesel consumption in the furnace without affecting homogeneity in heat treatment. This is achieved by

1. Increasing the pressure inside the furnace chamber by adjusting the damper plate in the exhaust gas pipe or chimney.
2. Utilizing the heat produced more effectively which includes.
   a. Pre-heating the air for combustion.''

II. FURNACE OPERATIONS

Different furnace operations or heat treatment processes carried out in Peekay Steels are Normalizing, Tempering, Annealing, Solution Annealing, Stress Relieving etc. All heat treatment process consists of Heating, Soaking and Cooling. All these processes are done at a specific rate depending upon the requirement. Heating means rising the temperature of the stock from room temperature to soaking temperature at a specific rate. Soaking means maintaining the temperature of the stock at soaking temperature for a particular time.Cooling means bringing down the temperature of stock to a predetermined temperature or room temperature at a particular rate depending up on the requirement.

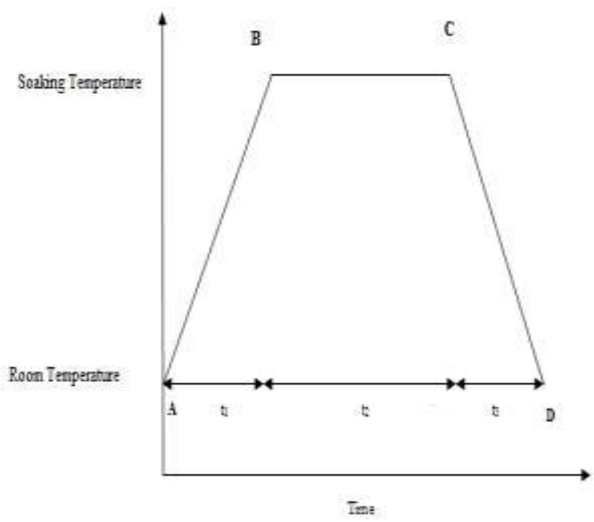

Figure 1 Graphical representation of heat treatment

All heat treatment processes can be represented graphically as shown above. It shows the variation of stock temperature with time. Here AB represents heating process, BC represents soaking process and CD represents cooling process. Area under the curve give an indication of energy absorbed by the stock. Time t_1, t_2 and t_3 are time of heating , soaking and cooling respectively. These times are used for calculation of SFFC. If cooling process are quenching, normal cooling or forced air cooling, then for calculation of SFFC time t_3 is not used. If cooling rate needed is less than the rate of above said cooling processes, time t3 will be used for SFFC calculation (For getting less cooling rate, fuel is to be burned)

III. FURNACE EFFICIENCY

Furnace efficiency (η_f) greatly depends up on Flame temperature, Air/fuel ratio, Furnace structure, Insulation level of furnace, Radiation loss from the furnace and Method of Furnace operation. Generally Furnace efficiency or Thermal efficiency is defined as the percentage of heat input that is effectively utilized to heat the stock.

$$\eta_f = \frac{\text{Heat in the stock } h}{\text{Heat in the fuel consumed for heating the stock}}$$

$$= \frac{M * C * (T - Tamp) * 1000}{L * \rho * Cv}$$

Let $(T-T_{amp}) = \Delta T$

$$\eta_f = \frac{M * C * \Delta T * 1000}{L * \rho * Cv} \quad (1)$$

Where

M ◊Tonnage of material processed in the furnace (*1000 kg)

C ◊ Specific heat of material processed in the furnace (490 J/kg/K)

T ◊Soaking temperature (K)

T_{amp}◊Ambient temperature (K)

L ◊Amount of diesel consumed in the furnace (Liter)

ρ◊Density of diesel (840 kg/m^3)

C_v◊Calorific value of diesel (43200 kJ/kg)

Here the fuel used to heat the stock is diesel

IV. SPECIFIC FURNACE FUEL CONSUMPTION (SFFC)

The efficiency of the furnace can be judged by measuring the amount of diesel needed per unit time per unit weight of the material. It is known as Specific Furnace Fuel Consumption (SFFC). It's unit is Liter/Ton/hr. As far as a furnace is concerned SFFC and Thermal efficiency are related very much deeply and constant can be introduced, known as furnace coefficient

SFFC = Amount of diesel consumed in liter per unit tonnage of material processed per unit Hour.

$$= \frac{L}{M * t}$$

$$\frac{M}{L} = \frac{1}{SFFC * t} (2)$$

(2) in (1) gives

$$\eta_f = \left(\frac{1}{SFFC * t}\right) * \left(\frac{C * \Delta T}{\rho * Cv}\right) * 1000$$

From the above equation we get a new equation relating furnace efficiency and SFFC with parameters furnace operating time and soaking temperature

$$\eta_f * SFFC = \left(\frac{\Delta T}{t}\right) * \left(\frac{C}{\rho * Cv}\right) * 1000 \quad (3)$$

Substituting the values of the constant (C, and C_v), we get equation (3) as

$$\eta_f * SFFC = \left(\frac{\Delta T}{t}\right) * \left(\frac{490}{840 * 43200 * 1000}\right) * 1000$$

$$\eta_f * SFFC = \left(\frac{\Delta T}{t}\right) * 13.344 * 10^{-6}$$

The constant $13.344*10^{-6}$ is known as Furnace Coefficient. This coefficient is dependent only on specific heat value of the material, which is processed in the heat treatment furnace, density of the fuel which is used to heat the stock and lower calorific value of the fuel. Usually performance of a heat treatment furnace is explained in terms of Specific Furnace Fuel Consumption (SFFC). The unit of Furnace Coefficient is kg/m^3/K.

V. EXPERIMENTAL SETUP

The experimental setup is shown in Figure 2. By operating the three valves simultaneously we can get, combustion air for burning of fuel with and without preheating. Closing the valve V1, V3 and opening V2, it is a system without combustion air preheating. Closing the valve V2 and opening the valve V1, V3 it is a system with combustion air preheating

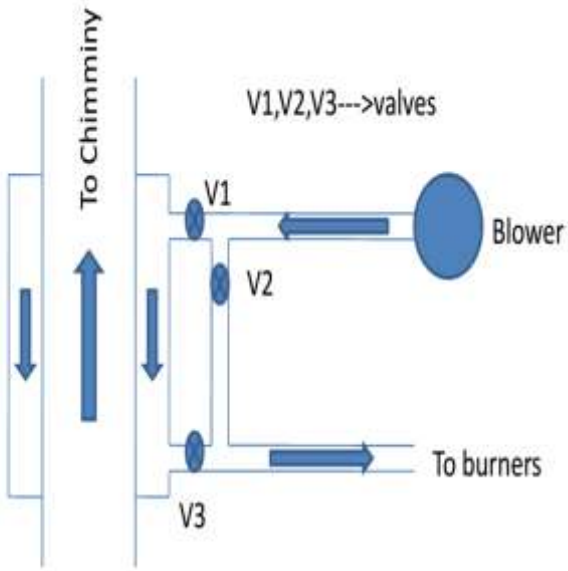

Figure 2 Schematic representation of APH with three valves

A Sandwich type valves is used for making these arrangements, ie for doing exhaust gas analysis with and without air-preheater (APH).

It is welded in the pipe way between blower and burner. Air preheating system is working with combustion air flowing in the counter clock wise direction around the chimney. Since area of heat transfer is more, radiation heat loss is more. Due to this, combustion air is not getting heated much. So the APH system around the chimney is insulated. The insulation on APH system is done by pasting ceramic wool around the system. For this Sodium Silicate is used as gum.

VI. RESULTS AND DISCUSSION

The fuel saving or the reduction in Specific Furnace Fuel Consumption with the introduction of combustion air pre-heating system for different furnace operations Normalizing, Stress Relieving, tempering and Annealing is as shown below.

Sl No:	Operation	Weight (kg)	Total Time (hr)	Reduction in SFFC (Lit/Ton /hr)	fuel savings (Liter)
1	Normalizing	6168	15.5	1.712	164
2	Stress Relieving	6244	10.9	1.274	87
3	Tempering	5509	15.8	0.696	61
4	Annealing	5956	15.7	1.672	156

Table 1 Fuel Savings with Exhaust Damper and APH System

The Table 1 describes the quantity of fuel saved for different operations. For Normalizing operation with an average weight of 6.168 Ton material for 15hr 30min operation 164 litre of diesel was saved.For Stress relieving operation with an average weight of 6.244 Ton material for 10hr 54min operation 87 litre of diesel was saved .For Tempering operation with an average weight of 5.509 Ton material for 15hr 48 min operation 61 litre of diesel was saved. For Annealing operation with an average weight of 5.956 Ton material for 15hr 42 min operation 156 litre of diesel was saved.

Emission Parameters	With Air Pre-heating	Without Air Pre-heating
Combustion Air Temperature ^{o}C	103	45
Flue Gas Temperature ^{o}C	544	634
Oxygen in %	14	12
Carbon dioxide in %	5	7
Carbon monoxide in PPM	33	46

Table 2 Exhaust Gas Parameters

With introduction of APH system Carbon Monoxide emission is reduced from 46 ppm to 33 ppm, ie combustion is improved by an amount 29 %. Flue gas temperature is reduced from 634^{o}C to 544^{o}C. With APH system combustion air temperature is increased from 45^{o}C to 103^{o}C.

VII. CONCLUSION

With introduction APH ie. Combustion Air Pre-Heating, (CO) Carbon Monoxide emission is reduced by 29 %. The other benefits obtained by the APH system are that, the temperature of flue gas is reduced and diesel consumption for different heat treatment processes are reduced.

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