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A CRITICAL REVIEW ON AN INVESTIGATION OF WASTE FLUE GASES THROUGH CHIMNEY

Amitesh Kumar	**Swati Gangwar**
PG Student, Department of Mechanical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur	Assistant Professor, Department of Mechanical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur

ABSTRACT

The analysis of flue gas released from chimney, temperature variation of flue gas, and design of masonry chimney in relevant to demand of industry. The flue gas dispersion from the stack (chimney) of power station / industry is investigated in order to utilization of heat wasted in form of smoke, different gases released. Exhausted flue gas temperature measurement and overall heat losses during flue gas emission through chimney occurs.The effect of convection and radiation for heat exchange process, the flue gas dispersion from the stack and high efficiency heat recovery facilities, Coal fire temperature analysis throughout overall burning process and discharge of flue gas after the treatment of particulate and toxic chemicals is key processes which are examined in this review study. Chimney design and construction processes for several industries also one of the reason to have temperature effect on inner and outer wall of stack.

Keywords: *Waste Heat, Chimney, Flue Gases, Heat Recovery, Convection, Radiation.*

INTRODUCTION

Chimneys are very long and hollow shaped cylindrical structure which provides ventilation for smoke from a boiler, stove, and furnace or used to eject hot flue gases at a higher altitude with efficient exit velocity [1]. It is found in power generation industries, brick industries, steel manufacturing industries, steam locomotives, buildings, and etc [2]. Chimneys are of different height according to their needs and demand of work.

Chimneys are built up of brick masonry, steel, reinforced concrete. During last few years the development of reinforced concrete chimneys instead of brick masonry and steel chimneys have turn out more popular because of their endurance and manufacturing cost. Thermal industrial chimney ranges up to 275 meter to 280 meters height as it eject heated flue toxic gases into the atmosphere at high inclination. Such types of chimneys are made up of reinforced concrete and it is weighted up to 50,000 tonnes [3].

From past few years energy consumption in India has become almost doubled which is totally dependent on fossil fuels. In year 2011-2012, 97% of Indian commercial energy supply was from fossil fuels like (coal, oil, and natural gases). Which is increasing day by day resulting in large industrial development? About 78 % of Indian industries are fully dependent on coal for power generation [4]. Large consumption of coal results in large emission of hot flue gases. These gases are toxic in orientation which ejected at higher altitude in atmosphere with the help of chimney.

In this research work the main focus is on the investigation of heat exhaust in a form waste flue gases through chimney, analysis of waste flue gases through chimney, methodology for reutilization of heat ejected, effect of temperature on chimney.

2. LITERATURE REVIEW

The purpose of this literature review is to provide and elaborate the current knowledge including overall findings as well as theoretical and experimental contribution on recovery of heat through waste flue gases of industrial stack (CHIMNEY) and the construction process of different industrial chimney.

Different information about the various issues in heat recovery or reutilization of waste heat ejected in form of flue gases through stack at high altitude in atmosphere has been shown. Consideration of different methods for the observation of ejected heat and their effects on chimney and environment, process of chimney model construction and the waste heat reutilization methods.

In this research work following points are discussed such as- Estimation of heat loss through chimney, Heat reutilization method, Effect of temperature on chimney wall, Chimney construction process.

2.1. Estimation of heat loss through chimney.

A heating system (power plant furnaces) is an interconnected system component that contributes to the reproduction and gets the heat for the utilization in different process buildings. After workful heat utilization rest of heat is lost in form of flue gases through stack (chimney). Shi Chang Wu et al. had investigated the flue gas dispersion from the chimney of power plant is considered for the high efficiency heat recovery from the ejected flue gases. Flue gas temperature decreases from ($115°C\ to\ 40°C$) by heat recovery process and it influence the local humidity and thermal NO_x level of the thermal power plant. In winter large atmospheric area is influenced by dispersion of flue gases [5]. Sivaji Seepana et al. had evaluated the utility of pelletized wood co-terminating with Indian coals which contains high fiery debris content. In this intrigue, this paper contemplate talks about pelletized wood (PW) co-terminating with high fiery debris content Indian coal by directing co-processing and co-terminating preliminaries in a 1000 kg/hr of pilot scale

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test office. Indian coals normally contains high powder content and less calorific esteem fills, along these lines, cooperation of coal amid its burning and statement of slag is examined in detail [6]. Mukesh Tiwari et al. had carried out the emission rate of flue gases through coal based power plant in India and consumption of coal in different power generation plants and ash content in Indian coals [7]. Lin Cui et al. had studied integrated assessment of the environmental and economic effects of an ultra-clean flue gas treatment process in coal-fired power plant [8]. G. Liu et al. had performed an experients on heat pipe heat exchanger in exhaust gas heat recovery system and studied their thermodynamic behavior of the heat pipe [9].

1.2. Waste heat reutilization.

Due to aboudent losses in thermal efficiency many methods were adopted to recover. Different processes were adopted for reutilization of this waste heat.Mahmoud Khaled et al. [10] had calculated the waste heat and the recovery of waste heat through chimney is done by heating the water through setups planting with in the chimney. A prototype is made and several experiments are done for heating of water through flue gases. Measurement of temperature is performed at several stage of heat recovery system. Flow rate of exhaust heated flue gases through pipes are also measured. This experiment shows that the radiation and the convection exchanges at the ground surface of the water tank significantly impact on the overall heat exchange rate of water used during experiment that is upto 70%. In this paper two experiments are done one for open pipe and other for closed pipe. When pipe is open water heated from $(10°C\ to\ 70°C)$ and when pipe is closed water heated upto $(10°C\ to\ 48°C)$ throughout one hour.

The energy provided in a form of coal and firewood burning is divided into two parts, (a) that is useful energy known as heating load and it is transferred to occupied space which is $80\%\ to\ 90\%$ of total energy and (b) $10\%\ to\ 20\%$ of remaining energy is transferred to exhaust gases. The main principle work shown in Figure 2 is done on exhaust gas which is connected with water tank. Water tank consist of several pipes in which exhaust gases is released and cold water is filled in tank from one side (B) and hot water released out from other side (A). After heating water cooled exhaust gases released out in the atmosphere. The transfer of heat takes place by the process of radiation and convection between exhaust gases and water filled in tank [11].

Moti L Mittal had estimated the emission of heat and pollutant through coal fired power plant in India. In India coal is used as primary fuel for electricity generation and its demand is increasing continuously year by year to meet the demand of power generation. This paper presents the emission rate of different gases through chimney like carbon dioxide(co_2), sulfur dioxide(so_2), nitric oxide(NO) [12].

2.3. Effect of temperature on chimney wall.

Different aspects are considered like temperature effects, wind effects, effects of loads during chimney design. Amithabaiju et al. had studied and analysis of tall reinforced concrete industrial chimney is done as per Indian standard codes for chimney. Third revision of IS 4998:1992 (part 1) as per IS code is used for design of RC chimney and its analysis is done and the location of Bellary in Karnataka is selected for the study [13].

During whole study the analysis of wind effect at top of chimney,analysis of thermal effect at inner and outer surface of stack wall is carried out and lateral deflection is carried out.

2.5. Chimney construction process.

During the design and construction of of industrial chimney Indian standard codes for chimney and building plays major role.K.Anil Pradeep et al. studied the different loads for the design of a 60m RCC flue stack is carried out [17]. Different IS codes like Draft Code CED38 (7892):2013, IS 1893(part 4):2005 etc were used for the chimney design and construction [15, 18].

Conclusions

[1] From all the above reviews it concludes that increase in environment temperature is due to one of the important reason of heat rejection from power industries.

[2] 18% to 22% of heat is ejected through chimney in form of flue gases, very few processes is optimized to recover or reuse of these heat energy.

[3] For design and construction of chimney, base diameter, top diameter, thickness of chimney, height and slant height plays an important role parameter.

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Figure 1:- General chimney diagram [1].

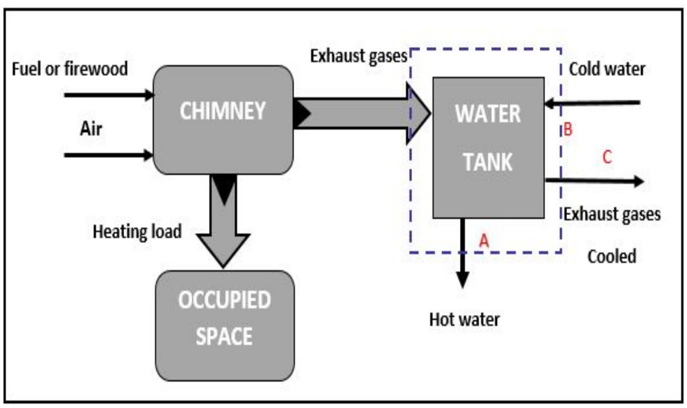

Figure2: - Block diagram for process of exhaust waste heat recovery system [10].

Temperature effect on chimney [13]

Increasing temperature of flue gas results in stresses development on chimney wall which results in temperature losses through wall. Different equation are derived accotding to Indian Standard Codes for chimney for the temperature effect on inner and outer wall of chimney [14, 15].

With increase in temperature inside the stack leads to maximum vertical stress.

$$f'_{CTV} = \alpha_{te} c T_x E_c \quad \text{……………… (i)}$$

Maximum stress in stack because of temperature increases in steel.

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$f'_{STV} = \alpha_{te}(c - 1 + \gamma_2)T_x E_s$ …….. (ii)

With increase in temperature at outside of stack leads to maximum vertical stress developed.

$f_{STV} = \alpha_{te}(\gamma_2 - C)T_x E_s$ …………. (iii)

T_x = temperature losses across the stack shell.

E_c = elasticity modulus of shell.

E_s = elasticity modulus of metal.

n = elasticity modular ratio.

ρ = ratio between the area of outside face vertical reinforcement to the area of stack.

γ_1 = ratio between inside face stack to outside face stack.

γ_2 = ratio between the distance of inner surface of stack shell and outer vertical reinforcement to the total thickness of the stack shell.

α_{te} = thermal coefficient concrete and reinforcing steel expansion.

$C = -\rho n(\gamma_1 + 1) + \sqrt{[\rho n(\gamma_1 + 1)]^2 + 2\rho n[\gamma_2 + \gamma_1(1 - \gamma_2)]}$ ….. (iv)

This equation shows the over all stresses developed due to temperature effects on the surfaces of the chimney.

Dead load is considered accordance to the IS 875 (Part 1):1987. During dead load calculation the weight of chimney shell, liners, liner supports, other appliances, load of ash and shoot is included [16].

Calculation along-wind load on a chimney.

Wind speed plays a major role in chimney construction as it affects the chimney, as it forms major external applied forces in the chimney design. Indian Standard Code of practice $IS: 875 - 1964^5$ opts wind pressure at static loads, the intenseness of which differs with height and the zone at which the chimney is located [16].

Gust factor method is used to calculate along-wind loads of a chimney. This method requires a data of hourly mean wind speed (HMW).

IS: 875(part 3):1987 is used to find out (HMW) speed at any height of the chimney (Z) [19].

Now,

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$$F(z) = \bar{F}(z) + \bar{F}(z) \quad \text{.......................... (v)}$$

$$\bar{F}(z) = \bar{C}_D d(z) \bar{P}(z) \quad \text{........................... (vi)}$$

$F(z)$ = load along-wind.

$F'(z)$ = fluctuating component of load along-wind.

$\bar{F}(z)$ = mean value along-wind.

C_d = mean drag-coefficient = 0.8.

$d(z)$ = outer diameter of chimney at each section.

Now,

Fluctuating component [17]

$$F'(z) = 3\frac{G-1}{H^2}\left(\frac{2}{H}\right)\int_o^H \bar{F}(z)zdz \quad \text{.......... (vii)}$$

Where
G = gust response factor.
H = height of chimney.
Gust response factor (G)

$$G = 1 + g_f r \sqrt{B + \frac{SE}{\beta}} \quad \text{....... (Viii)}$$

g_f = peak factor

$$g_f = \sqrt{2\ln(VT)} + \frac{0.577}{\sqrt{2\ln(VT)}} \quad \text{.. (ix)}$$

$$VT = \frac{3600 f_1}{\left(1 + \frac{B\beta}{SE}\right)^{1/2}} \quad \text{............. (x)}$$

V = effective cycling rate.
T = time taken as 3600 seconds.
r_t = Doubling of turbulence intensity.
$r_t = 0.622 - 0.178 log_{10} H$.... (xi)

B = back ground factors

$$B = \{1 + \left(\frac{H}{265}\right)^{0.63}\}^{-0.88} \quad \text{......... (xii)}$$

E = amount of available energy at natural frequency in the wind.

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$$E = \frac{123\left(\frac{f_1}{\bar{V}(10)}\right)H^{0.21}}{\{1 + (330\frac{f_1}{\bar{V}(10)})^2\ H^{0.42}\}^{0.83}}$$ …. (xiii)

S = reduction factor size.

$$S = \{1 + 5.78\left(\frac{f_1}{\bar{V}(10)}\right)^{1.14} H^{0.98}\}^{-0.88}$$ .. (xiv)

$\bar{V}(10)$ = hourly mean wind speed from the ground surface to n meter height of the chimney (m/s).

f_1 = natural frequency of flue stack (H_z).

B = 0.016 = critical damping factor as structural damping along wind load.