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Review of Analysis of Heat Recovery from Top Coat Oven Exhaust in Paint Shop

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Abstract— **Presently in paint shop there are in all three ovens i.e. ED oven, Primer oven and Top coat oven. Our main focus is on (top coat) TC oven. Currently, the high temperature exhaust in this oven is directly passed to the environment. The exhausted flue gas is around 340°C. The proposed system is to reuse that hot exhaust air for hot water generation. The hot water generated will be at temperature of 110°C approximately. The generated hot water then can be used for pre-treatment and oil conservation process. Heat energy for total hot water heating is 1253 KW. Hence the potential of energy recovery & reuse is realized. Average 885 KW of energy can be recovered from TC oven exhaust. The proposed system will consist of Shell & tube heat exchanger with counter flow arrangement. Sometimes situations occurs where first the flue gases from oven condenses i.e. when temperature goes below 105°C and secondly the water enters to water-vapor state i.e. when water temperature goes above 110°C, in these situations the gases are directly bypassed without involving the gases to pass through the heat exchanger using thermal sensors. The main motive of this proposal is to reuse the heat generated by TC oven for generation of hot water. The equivalent exhaust energy from top coat oven is 932KW. According to proposed system we will get 90% efficiency in heat recovery i.e. 885KW energy. The exhaust air flow rate is 12000nm^3/hr. The heat carrying flue gas is exhausted to atmosphere at 340°C after exchanging heat with individual heating zones of the oven. The use of heat from oven is to generate hot water (110°C) which will be supplied to pretreatment and oil conservation process. This reuse of heat will save the energy along with the CNG consumption required for boiler to heat the water.**

Keywords— ***Heat recovery, Paint cure oven, Shell and tube heat exchanger, Energy conservation***

I. INTRODUCTION

Paint curing ovens are considerably long in length which consists of different zones in it. Each zone has its own task & importance. There are two heating zones through which car body passes & drying of paint on the body takes place. The purpose of providing two heating zones in it is to gradually heat the body by maintaining higher temperature in the second heating zone than the first one. Because, if we heat the body by suddenly exposing to higher temperature there may be the possibility of damaging the paint on car body. Then after heating zone there is a holding zone in which constant temperature is maintain & after that cooling zone in which cool air is blowing on the body to cool the heated body. To avoid the heat transfer from one zone to another air seal is used in oven which prevents the heat transfer. The steel construction is the skeleton of oven. As the oven has to bear static loads, it is necessary to have a strong underbody. The steel construction bears the actual oven with conveyor. Due to continuous heating steel expands so the tunnel of the oven should compensate this expansion at expansion points. Normally, oven expands 1mm on heating by 100°C, so according to this length of the oven determined for the compensation on expansion. Insulation used for the oven is rock wool to save the energy & to avoid the rise in temperature of the workshop unnecessarily. The insulation used for the oven must be water repellent & fire proof. Heat transfer to the body is by convection. At the startup of the oven ambient air is admitted inside the oven through air breather & then to the filters. The heat energy at high temperature from the incinerator exchanges the heat exchanger with ambient air which is taken inside the oven. So there is no direct contact between the heat energy from incinerator & the air inside the oven. Only exchanging of heat takes place.

II. LITERATURE REVIEW

F. Pask, J. Sadhukhan b, P. Lake, S. McKenna, E.B. Perez, A. Yang, [1] Systematic approach to optimize the oven by using DMAIC technique is the powerful tool to save the energy up to large extent. DMAIC method has been used to cure adhesive on masking tape web. LEL level of the oven had been maintained within a range which shut the system if it goes below 35%. By performing experiments they concluded that if adjusting the damper positions lots of energy can be save. Annual gas saving is 16, 58,000 kWh. By increasing the heat transfer coefficient faster drying rates can be achieved

.**A.Lozano, F Barreras, N. Fueyo, S Santodomingo, [3]** This paper numerically investigated the thermal hydraulic performances for various OSF fins with well validated 3D models. The roposed ones provide well-adapted predictions for OSF fins with different fin thickness covering a broad range of blockage ratio, while previous ones only adapt to the thinner fins & apparently deviate from higher blockage ratios.

Jongyeok Lee, Kwan-Soo Lee, [4] has analysed that the friction factor f & Colburn factor j were found as functions of the various geometrical parameters, Researcher carried out an unsteady numerical analysis using a large eddy simulation to investigate the fluid flow in chevron-type plate heat exchangers. The flow consisted of a stream wise component and a component in the furrow direction. The friction factor f and Colburn factor j were found as functions of the various geometrical parameters, i.e., 30o < β < 60o and 2.0 < p/h < 4.4, and the performance of the heat exchanger was characterized using the JF factor. Both f and j increased as b increased and as p/h decreased.

Yujie Yang, Yanzhong Li, [5] this paper numerically investigates the thermal hydraulic performances for various OSF fins with well validated 3D models. The proposed ones provide well-adapted predictions for OSF fins with different fin thickness covering a broad range of blockage ratio. The proposed ones provide well-adapted predictions for OSF fins with different fin thickness covering a broad range of blockage ratio, while previous ones only adapt to the thinner fins & apparently deviate from practice at higher blockage ratio. [2014]

T. G. Walmsley, M.R.W. Walmsley, M. J. Atkins, J. Hoffman-Vocke, J. R. Neale, [6] has concluded that tube shape has a significant impact on the j/f and jf/f ratios. Assuming these ratios account for heat transfer, gas flow resistance and foul ability, the recommended tube for exhaust gas heat recovery is elliptical tube. The ellipse shape tube produced a j/f ratio 100 % and 120 % higher than that of round tube for the two arrangements considered. The flattened round tube is also effective, given enough spacing between the tubes, and may be a good solution.

Guo-yan Zhou, Ling-Yun Zhu, Hui Zhu, Shan-tung Tu, Jun-jie Lei, [10] This research presented the simplified and accurate model for temperature distribution in the shell and tube heat exchanger. Two examples of BEU and AES heat exchangers with single-phase fluid are analyzed to demonstrate the application and accuracy of the proposed model in temperature distribution, compared with the Cell model and HTRI. The research shows that the proposed model reproduces the temperature distribution given by the HTRI solution on the tube side flow with 0.19% accuracy for the BEU heat exchanger and 0.35% for the AES heat exchanger. Two engineering cases have been introduced and the results show that the calculated temperature is more accurate than that by Cell model and agrees well with that by HTRI program. It should be noted that the proposed model can be successfully used for all shell-and-tube heat exchangers with straight tube or U-tube types.

Wang Yongqing, Gu Xin, Wang Ke, Dong Qiwu, [11] Researcher addresses that analysis of fluid flow and heat transfer characteristics were carried out with different shaped baffle namely segmental, rod and H-shaped support structures in shell-sides of shell-and-tube heat exchangers, by using numerical models. At the same flow flux, both the heat transfer coefficient and flow pressure drop in shell-side of H-shape baffle heat exchanger lie between that of segmental heat exchanger and ROD baffle heat exchanger. In shell and tube heat exchange at shell-side of heat exchanger, at some range of flow flux, H-shape baffle is an ideal tube support structure, which induces fluid flows in a mixing pattern and enhances greatly heat transfer. The characteristics of shell-side of H-shape heat exchanger combine that of cross flow and longitudinal flow. The H-shape heat exchanger merits both heat exchangers with cross flow in shell-side and with longitudinal flow in shell-side.

K. Srinivasana, S. Muthu, S. R. Devadasan, C. Sugumaran, [*12*] This research addresses the pilot implementation of Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) phases to improve the effectiveness of shell and tube heat exchanger in a small sized furnace manufacturing company. Shell and tube heat exchanger is one of the critical components of the furnace. The imperative objective is to improve the quality of the furnace through DMAIC phases. Six Sigma DMAIC methodologies were implemented in the furnace manufacturing company to reduce the thermal energy in exhaust flue gas which extremely impacts the efficiency of the furnace. Thus, DMAIC phases revealed that, the best solution to the shell and tube heat exchanger by increasing heat transfer rate and reducing thermal energy in the waste flue gas through implementation of circular fins over bare tubes.

Preetham P. Rao, Ashok Gopinath, [2] concluded that paint oven consumes typically over 17% of the total energy spent in the paint shop. It was observed that the carriers are almost as heavy as the BiW it carries, and hence a significant portion of energy is spent to heat them up within the oven. So the usage of the shroud in a real oven with a BiW of an SUV showed over 20% reduction in the energy consumed by the carriers.

III. CONCEPT & MECHANISM

A. Concept:

Conservation of energy is the basic need for any industry because cost of energy is increasing day by day. The concept behind the heat recovery is to reuse the heat which has been exhausted to atmosphere without using it. With the use of exhaust which has high heat energy around 932kW we can recover around 885kW of energy considering 90% efficiency. This recovered heat energy can be utilized to heat the water which is used for various industrial processes. Currently, temperature of exhaust gases from oven is ranging from 280^{o}C -340^{o}C. Shell & tube heat exchanger will be use to exchange the heat from high temperature exhaust gases to heat the water which is heated by boiler. So the energy required to heat the water by boiler will be save. CNG gas is used to heat the water which will be considerably saved.

B. Mechanism:

Current System design does not allow recovery or reuse of the high temperature gas as shown in the fig.1

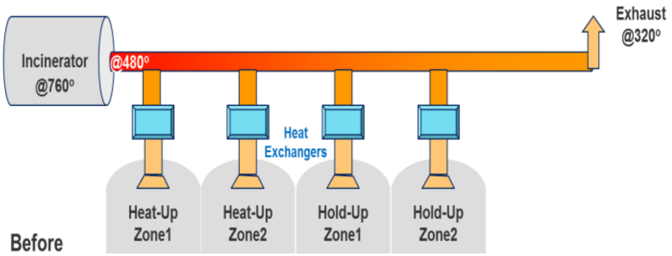

Fig.1 Current Oven exhaust system

By installing heat recovery system ~885KW Heat energy equivalent can be recovered. This will be used to heat the water as shown in fig 2.

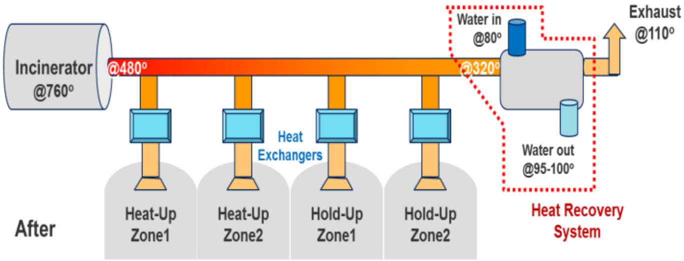

Fig.2 Proposed Heat recovery system from the oven exhaust

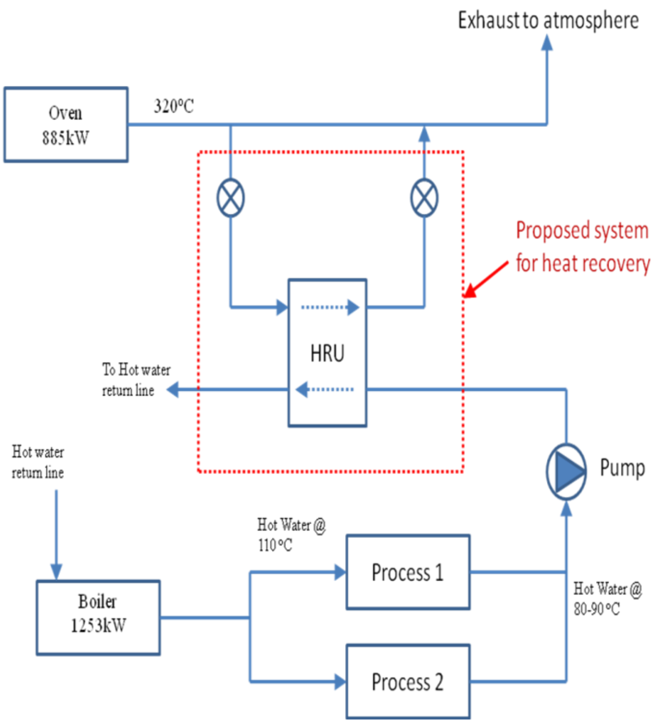

Fig. 3 Schematic of heat recovery system

Fig. 3 shows the schematic of heat recovery system in which shell and tube heat exchanger will be used to recover the heat from the high temperature oven exhaust which is at 280°C to 340°C. Pump is used draw a water from return line of hot water which will be fed into the heat exchanger at around 80 °C to 90°C and then it will be heated around 110 °C and that hot water will be again connected to the main water line so that water will be preheated and less CNG will required for boiler to heat the water so that energy conservation takes place along with cost for CNG will be save.

The main heart of the proposed heat recovery system is the heat exchanger which is shell & tube heat exchanger with counter flow arrangement. The purpose of selecting this type of heat exchanger is that we will get a highest efficiency and to transfer equal amount of heat parallel flow heat exchanger is larger in size as compared with counter flow heat exchanger. Hence counter flow heat exchangers are generally preferred. LMTD & effectiveness are the two important terms while designing the heat exchanger. LMTD for counter flow heat exchanger is larger than LMTD for parallel flow heat exchanger & is given by,

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left[\frac{\Delta T_1}{\Delta T_2}\right]} \quad \ldots (1)$$

Where,

For counter flow,
$\Delta T_1 = Th_o - Tc_i$
$\Delta T_2 = Th_i - Tc_o$

For parallel flow,
$\Delta T_1 = Th_i - Tc_i$
$\Delta T_2 = Th_o - Tc_o$

Thi & Tho is the hot fluid inlet and outlet temperatures respectively.
Tci & Tco is the cold fluid inlet and outlet temperatures respectively.

To reduce the pressure drop on tube side there should be decrease number of tube passes, increase tube diameter & on shell side need to increase the baffle cut & baffle spacing, increase the tube pitch. To increase a heat transfer rate we need to increase the heat transfer coefficient so in tube side we need to increase the number of tubes & in shell side need to decrease the baffle spacing. To enhance the heat transfer rate we need to increase surface area & effectiveness also.

Heat recovery calculations:

Exhaust Energy (Q) = $\rho \times V \times C_p \times \Delta T$ ……………. (2)

Table 1: Heat Recovery Calculation Parameters

Description	Unit
Exhaust air flow rate (V)	Nm3/hr
Density of air (ρ)	Kg/ Nm3
Specific heat of air (C_p)	Kcal/Kg°C
HRU inlet & outlet temperature (ΔT)	°C
Equivalent Exhaust energy (Q)	KW

Heat load requirement

Average CNG consumption per day

Average CNG consumption per hour

II. Conclusion & Future Work

As the heat recovery from the system is huge so the potential of energy recovery can be realized. The recovered heat can be used to heat the hot water which can be used for the pretreatment and oil conservation process. The wastage of such a high heat content energy can be prevented. The current situation is that schematic flow through the system is finalized and design of heat exchanger is in process which will help in to recover the heat.

Acknowledgment

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