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EXPERIMENTAL AND CFD ANALYSIS OF WASTE HEAT RECOVERY SYSTEM FOR E-COAT OVEN EXHAUST

Nivedan Mahato[1*], Ranjeet Kumar[1], Dr. Padmaja Tripathy[1]
[1]Assistant Professor, School of Engineering & IT
ARKA JAIN University Jharkhand

Abstract : The specification of a heat recovery device for an oven in a paint shop is presented in this article. The hot air produced in the oven is directly expelled into the atmosphere through the exhaust. At High Temperature, the unused heat from the oven is released into the atmosphere. The flue gas carrying the depleted heat is extremely hot. The air will be reused in the system to produce hot water. The hot water created will have a temperature similar to that of boiling water. This water can then be used in a variety of processes. The amount of heat energy needed for complete hot water heating is enormous. As a result, the energy recovery and reuse potential is realized. The total amount of energy recovered from oven exhaust is 90%. Heat exchanger with gas to liquid heat transfer is the method used.

keywords: Shell and tube heat exchanger, waste heat recovery, CFD, Counter flow heat exchanger

I. INTRODUCTION

ED, PTED, and ELPO ovens are all examples of E-coat ovens. One of the most important steps in the serial painting of automobiles is the E-Coating process, also known as cataphoretic painting. The pieces are rinsed and sent through the E-coat bake oven to dry and cure after the Electro-coat is applied by submerging them in the E-coat tank. The E-coat oven is the hottest oven in the paint shop at temperatures of 1760C. The oven is typically split up into two or more sections. The first section is the heat up zone. The heat-up zone's job isn't to cure the component; rather, it's to get the vehicle or part up to temperature. An automotive vehicle body's heat-up zone is usually 10 minutes. Depending on the type of paint or coating being cured, the temperature set point will differ. The Electro coat paint is allowed to cross-link and harden for 20 minutes at room temperature. Since E-Coat is a water-based coating, the E-coat oven contains very little volatile organic compound, but it does emit smoke at high temperatures when the E-Coat drips off onto the hot oven surface.

Table 1 shows the operations that take place during the E-Coating process. The maximum temperature of hot gases emitted through the exhaust during E-Coating is described in the table below, ranging from 1500C to 2000C.

The focus of this paper is on repurposing waste heat from high-temperature smoked gases for other purposes. A counter flow heat exchanger is used to use this hot gas. To save energy and prevent overheating the workshop, all free channels and the oven tunnel should be insulated with rock wool [1], as well as fire-proof and water-repellent insulation. The waste heat is recovered using a shell and tube counter flow heat exchanger for exhaust gas. According to the survey, by using waste heat, overall productivity can be improved. Inlet air can be preheated using waste heat. According to this report, recovering hot gas using a waste heat recovery system will save up to 8% in annual costs.

Table 1 The E-coating process and drying process conditions

Operation	Process Parameters
Pre-Treatment Phase	Washing cycle at 60 0C for few minutes phosphating (anticorrosive treatment) with lightly acid
Cataphoretic deposition phase	Cathodic electrode composition in pain bath tank- tension 300 volts, 300C, 3 minutes. Furnace up to 185 0C for 20-30 minutes
First pain deposition phase	Paint drying furnance up to 1600C, for 20-30 minutes
Final Paint deposition phase	Final paint drying furnace up to 1500C, 20-30 minutes

II. RELATED WORK

Every day, the amount of energy consumed rises. According to data from India's central electricity authority, 1,291,494 GWh of energy was consumed in 2020, and meeting potential energy demand would be more difficult. One way to conserve energy is to recycle energy from waste heat. The highest temperatures, but the smallest quantities of waste heat, are available directly from the product, while the lowest temperatures, but the largest amount of heat, are available at the plant level. This means that appropriate waste heat recovery (WHER) sinks are unlikely to be found at lower levels, but may be found at the same or higher levels. The three options for energy recovery are to reuse it for the same reason, recover it for a different use inside the plant, or repurpose it for energy storage or power generation (i.e. electricity).

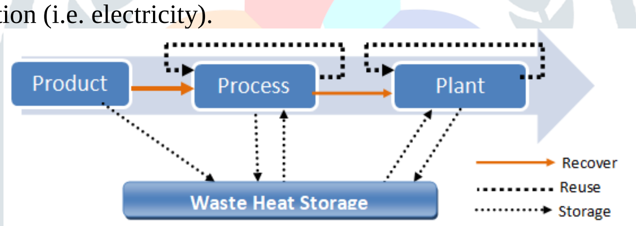


Figure 1 perspective for WHE

Brückner, S., Liu, S., Miró, L., Radspieler, M., Cabeza, L. F., & Lävemann, E. (2015)[] According to their report, absorption chillers are profitable for Real Estate consumer types and for Enthusiast consumer types when run for at least 2500 hours per year. To be profitable for Industry customers, more than 6500 hours per year are needed. Furthermore, for Industry market groups, absorption heat pumps are profitable beginning at 3000 hours, while for the rest, even fewer operating hours are economically feasible. Finally, there are user styles for Real Estate and Enthusiasts, when industrial consumer types operate for more than 4000 hours a year, the maximum appropriate investment cost is already at or above the current day investment cost of the technology. When deciding whether a process can generate useful waste heat or can use waste heat as an energy source, temperature is one of the most important factors to consider.

Qin, Y., Lv, X., Bai, C., Qiu, G., & Chen, P. (2012) the current study proposes a novel waste heat-recovery method based on molten BF slag. The experiment validates the feasibility of the waste heat-recovery method proposed in this report. The amorphous and spherical slag particles formed by the Rotary Multinozzel Cup Atomizer process. The key combustible compositions in gas products are CO, H2, CnHn, and CH4.

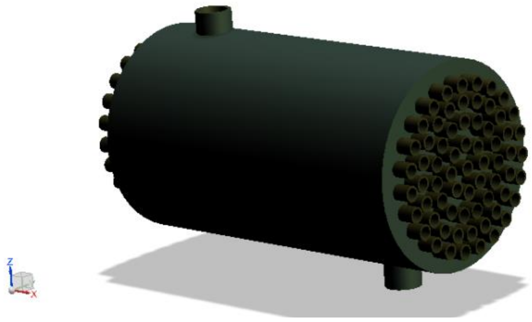
Wang Yongqing, Gu Xin, Wang Ke, Dong Qiwu (2011) The researcher claims that numerical models were used to analyse fluid flow and heat transfer characteristics in shell-sides of shell-and-tube heat exchangers with different shaped baffles, such as segmental, rod, and H-shaped support structures. At the 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. Both the heat transfer coefficient and the flow pressure decrease in the shell-side of an H-shape baffle heat exchanger are between those of a segmental heat exchanger and a ROD baffle heat exchanger at the same flow flux. At certain flow fluxes, an H-shape baffle is an ideal tube support system in shell and tube heat exchangers, which induces fluid flows in a mixing pattern and decreases heat transfer losses and with longitudinal flow in shell-side.

III. MATERIALS AND METHODS

Heat exchanger

A heat exchanger with a shell and tube design is a method of heat exchanger. It's the most popular heat exchanger in petrochemical plants and other large chemical processes, and it's ideal for high-pressure applications. This type of heat exchanger contains of a shell (a large pressure vessel) with a bundle of tubes inside it, as the name implies. To transfer heat between the two fluids, one fluid flows through the tubes and another fluid flows over the tubes (through all the shell).

For use of waste heat from the paint shop, a counter flow heat exchanger was considered. The fluids join the heat exchanger from opposite ends in counter-flow heat exchangers. Since the average temperature difference over any unit length is greater, the counter current design is the most effective in terms of transmitting heat from the heat (transfer) medium per unit mass. The CAD modal of the heat exchanger shown in below diagram



schematic diagram is shown in below fig 2

EXPERIMENTAL APPARATUS AND PROCEDURE

The experimental setup was installed in nearby paint Shop Company at Jamshedpur. The exhaust gas was collect through the duct from the paint shop chimney

Fig 3(a) paint shop floor

Fig 3(b) close view of paint shop

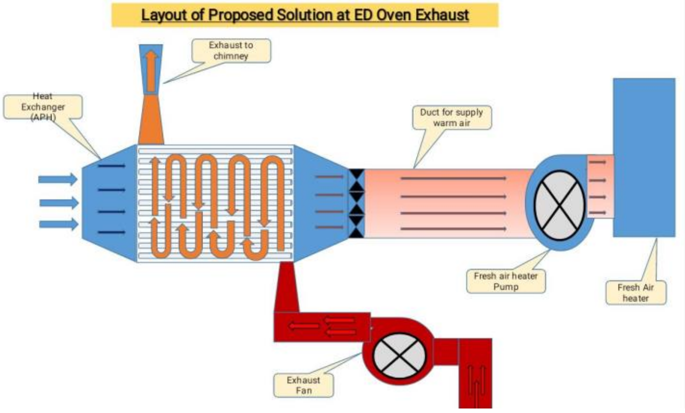


Fig 4 Schematic Diagram of Experimental setup

EXPERIMENTAL PROCEDURE

Temp Reading

Temperature of exhaust gas				
In	141	143	144	142
Out	130	129	128	131
Temperature of intake air				
in	20	21	20.5	21.5

AIR TO AIR HEAT EXCHANGE

Exhaust Air:

$v = 9980\ \frac{m^3}{hr}$

T_{inlet}=143°c

T_{outlet}=130°c

Cp=1.01433 kj/kgk

ρ=0.85kg/m³

$$Q_{exhaust} = \frac{9600}{3600} \times 1.0047 \times 10^3 \times .85(143 - 130)$$

$$Q_{exhaust} = 1072 \text{ watt}$$

For Heat Exchanger:

Calculation of 4th temp (T_{outlet} of intake air)

$$31072 = \frac{9600}{3600} \times 1.0047 \times 10^3 \times 1.2(T_x - 20)$$

$$T_x = 9.66$$

Design of "counter flow" shell & tube heat exchanger:

Q_1= 143-29.33 =113.34

Q_2= 130-20= 110

$$LMTD(Q_m) = \frac{Q_1 - Q_2}{\ln\left(\frac{Q_1}{Q_2}\right)}$$

Q_m=112.1

Tube Geometry

Q=31072 watt

We have chosen mild steel tube having

h=7.9 watt/m²K

Assume

d=0.030m L= 1.5 m

$Q=hAQ_m$

$$31072 = 7.9(n\pi \times 0.03 \times 1.5(112 + 273)$$

n=73 tubes

IV. RESULTS AND DISCUSSION

Counter flow heat exchanger is used so the flow of hot fluid which connected with paint shop duct and cold fluid is use to in from small diameter tube of the heat exchanger. The direction of cold and hot fluid flowing is opposite to each other. Fig 5 shows the contour diagram of temperature distribution inside the heat exchanger. The temperature of cold fluid gradually increase and temperature of hot fluid is decrease and out from the outlet channel the red color showing the high temperature and blue line is showing low temperature of the heat exchanger.

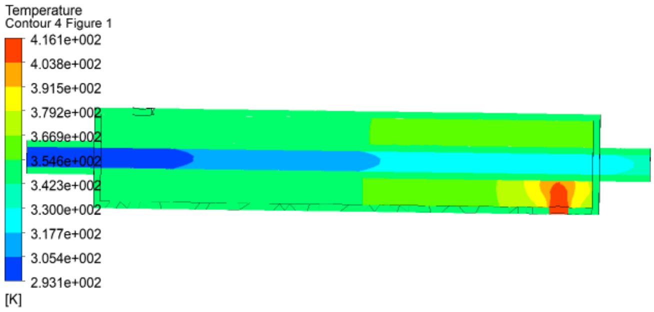


Fig 5 counter diagram of Temperature Distribution of shell and tube heat exchanger

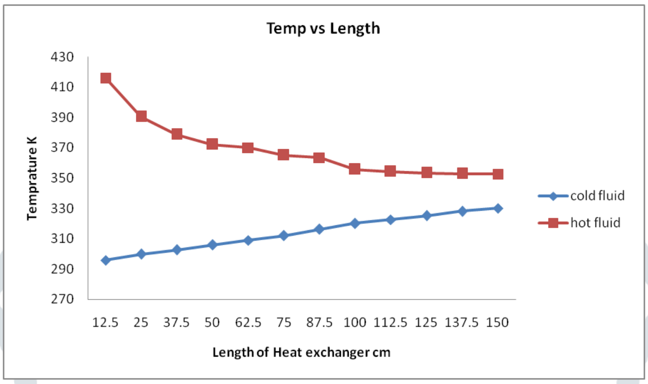


Fig 6 Graph between Temperature and length of the heat exchanger

Above graph show the temperature of hot fluid which is flow inside the shell and cold fluid which is inside the tube. The temperature of the hot fluid is decrease during the flow over the cold tube and clod fluid temperature is gradually increased through the length of the shell tube heat exchanger.

The pressure contour diagram is shown in the below fig 6. It explain the pressure inside the shell and tube heat exchanger the red zone or hot fluid inlet area have more pressure due to duct is connected with blower. The pressure inside the cold fluid channel is not much.

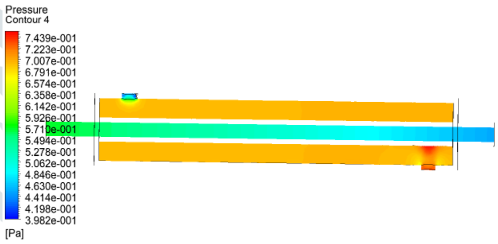


Fig 7 counter diagram of Pressure Distribution on shell and tube heat exchanger

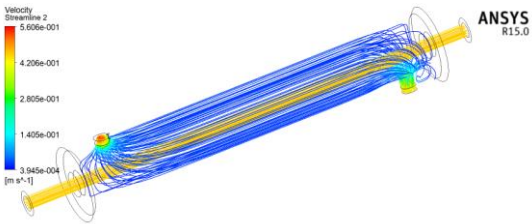


Fig 8 Streamline diagram of fluid flow inside the Shell and tube heat exchanger

Fresh air heater unit

Physical quantity	Before	After
Volume	9600 m3/hr	9600 m3/hr
Density	1.2 kg/m3	1.2 kg/m3
Specific heat	1.0047Kj/Kg-K	1.0047Kj/Kg-K
T1	1430C	1430C
T2	200C	29.660C
Q	94.5148Kcal/s	87.0919Kcal/s
Mgas	30.9321 Kg/Hr	29.5025Kg/Hr

Net saved mass gas is 2.43Kg/Hr and saving of gas in percentile is 8%

Total running hour in per day is 8 hr accordingly total working in a year is 2496hrs/year the mass of gas can be utilize 6063.5 Kg per and saving is approx 151588 Rs/year

REFERENCES

[1] Brückner, S., Liu, S., Miró, L., Radspieler, M., Cabeza, L. F., & Lävemann, E. (2015). Industrial waste heat recovery technologies: An economic analysis of heat transformation technologies. Applied Energy, 151, 157-167.

[2] Qin, Y., Lv, X., Bai, C., Qiu, G., & Chen, P. (2012). Waste heat recovery from blast furnace slag by chemical reactions. Jom, 64(8), 997-1001.

[3] Wang Yongqing, Gu Xin, Wang Ke, Dong Qiwu, Numerical investigation of shell-side characteristics of H-shape baffle heat exchanger, The Second SREE Conference on Chemical Engineering, Procedia Engineering 18 (2011) pp. 53 – 58

[4] Thakare, M. S. S., & Hole, J. A. Analysis of Heat Recovery from Top Coat Oven Exhaust in Paint Shop.

[5] Warahena, A.S.K., Yew Khoy Chuah "Regenerative Heat Recovery - Its Industrial Applications" Inst. of Mech. & Electr. Eng., Nat. Taipei Univ. of Techno.,Taipei; Information and Automation for Sustainability, 2007. ICIAFS 2007.