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WASTE HEAT RECOVERY IN GALVANISING INDUSTRY

İbrahim KILIÇASLAN[*], Durmuş KAYA[**], Süleyman SAPMAZ[*]
[*]Kocaeli Üniversitesi, Teknik Eğitim Fakültesi, Makina Eğitimi Bölümü, Umuttepe, Kocaeli, Turkey
[**]Karabük Üniversitesi Enerji ve Çevre Teknolojileri Birimi (KBU ENÇET), Karabük, Turkey

Abstract

Primary energy consumption in Turkey reached the level of 105 million tons of oil equivalent in 2010 [1]. Since Turkey meets 3% of its oil and gas demand from domestic sources, it is a major energy importer.
When energy consumption of sectors are taken into consideration, industry sectors take first place. The ratio of energy consumption in industry is at the level of 47% of the total energy consumption of Turkey.
Energy consumption has an important effect on the environment which suffers some problems caused by air pollution, sustainable production and competition of industry. As the cost of energy is an important factor in industrial production, energy conservation has become very crucial in today. Energy conservation is the practice of using energy more efficiently by recovering wasted energy.
In this study, a waste heat recovery system namely "recuperator" has been applied to the galvanizing industry fuelled by natural gas. A 42.2 Nm^3/h natural gas is consumed and flue gas at 350^oC is discharged into the atmosphere by galvanizing furnace. After the application of recuperator, the temperature of the flue gas was decreased from 350^oC to 150^oC, and hot air was produced at about 110^oC in preheating galvanized products. By using waste heat recovery system, the energy conservation was performed as about 15%.
Keywords: Energy conservation, waste heat, efficiency, recuperator, galvanizing

1. Introduction

One of the most common failures in industrial metal applications is corrosion. Corrosion is the deterioration of a material due to interaction with its environment. It is the process in which metallic atoms leave the metal or form compounds in the presence of water and gases [2].

The total national yearly cost of metallic corrosion in the United States was estimated at $167 billion in 1985 [3].

The corrosion being seen in industrial and offshore applications has many different types. It depends on its occurrences and failure mechanisms. The most familiar type of corrosion is uniform corrosion.
Galvanizing is the best protection method from corrosion to metals. Life period of a galvanized steel used industrial or offshore applications reported as 20-40 years and it reaches to a 50-100 years in mild environments [4].

Galvanizing is a traditional coating technology with 200 years history. The most important distinguish point of galvanizing from other coating techniques; it provides more powerful coating because of chemical reactions forming in the interface. Galvanizing forms are a metallurgical bond between substrate and molten zinc layers. The molten zinc reacts with the surface of the steel or iron to form a series of zinc-iron alloy layers.

In order to perform a high quality galvanize coating pre-cleaning operations are vital. Firstly grease and paint are cleaned by soaking in a hot alkali solution. The solution maybe a caustic soda combined with an emulsifying agent and detergent. Ideal temperature of the caustic tank is 140 ^oC and little maintenance is required of this tank except the periodic addition of chemicals to maintain solution strength. Water rinsing

Corresponded Author; ikaslan@kocaeli.edu.tr

follows this step. Metal part is cleaned with water to protect chemical concentration of other tanks. Acid pickling next removes rust that formed on the metal surface. Hydrochloric acid and sulfuric acid are commonly used chemicals for pickling. After this step the metal part should be rinsed to prevent acid contamination. A wetting agent or flux is needed to promote uniform wetting of zinc. In order to provide uniform wetting, zinc aluminum chloride is commonly used. Basically metal part is dipped in to a flux tank as above.

The distortion risk can be considered for some applications. It occurs because of thermal difference between molten zinc (840 ^{o}C) and cold metal part (100 ^{o}C). It causes shape distortion of solid metal part. The best technique of avoiding distortion is preheating metal to 230 ^{o}C before dipping into molten zinc.

The prepared metal is dipped into a tank of molten zinc which is kept at approximately 840 ^{o}C. To perform certain properties, zinc tank may include aluminum, nickel or lead. The metal is cooled by quenching or allowed air cool depending on product type. After that galvanized metal is inspected, weighed and stored to shipping. Figure 1 shows schematic view of galvanizing process.

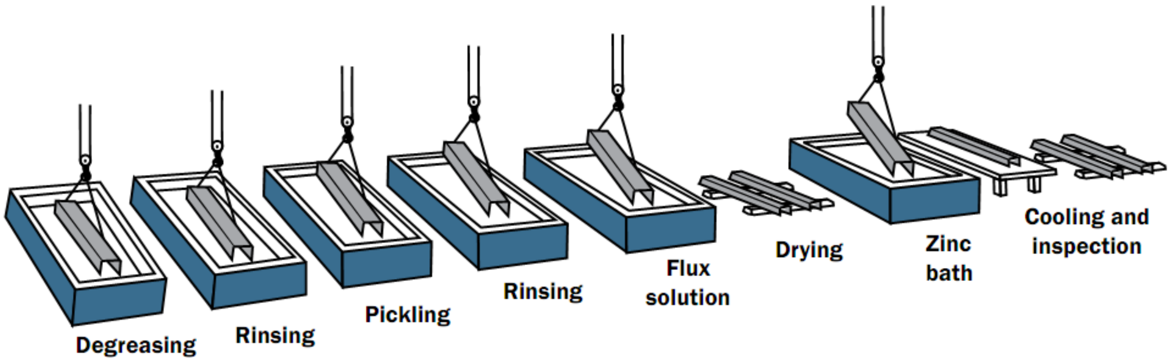

Figure 1. Schematic View of Galvanizing Process [5]

2. Heat Conservation in Galvanizing Process

One of the main costs of galvanizing process is energy. Natural gas furnaces are being used to heat tanks. Efficiency of a modern furnace is approximately %65. It means the %35 of natural gas is wasted. Heating system of pickle solutions is the other main consumer of natural gas. The caustic tank is heated to 180 ^{o}C to insure removal of oil, and the rinse tanks are operated at 100 ^{o}C to allow the metal to be moved into the pickle tanks while warm. As we consider a 30 m^3 tank of molten zinc at 840 ^{o}C the amount of natural gas burned becomes extreme.

Preheating process in galvanizing industry is another important point. Since interstitial stresses cause distortion and mechanic deformation on the surface of materials. By means of a preheating process heated metal up to 230 ^{o}C is capable of preventing distortion. Flue gas of galvanizing furnace can provide this heat energy with a recuperator application.

3. Energy Conservation by Using a Recuperator

Waste heat is generated in galvanizing process by natural gas combustion in furnace and dumped in to environment at about 350 ^{o}C. It is possible to waste heat recovered from flue gas by using Recuperators. A recuperator is gas to gas heat exchangers operating in medium-high temperature ranges. In the recuperator, heat exchange occurs between the high temperature flue gasses and the air through tube walls. The recuperator exchanger has a simple design. Hot flue gases travel in several small diameter pipes contained within the shell of the recuparator. Cooler fresh air then passes over these pipes absorbing much of the thermal energy. The recuperator which recover waste heat from high temperature flue gas is shown in Figure 2.

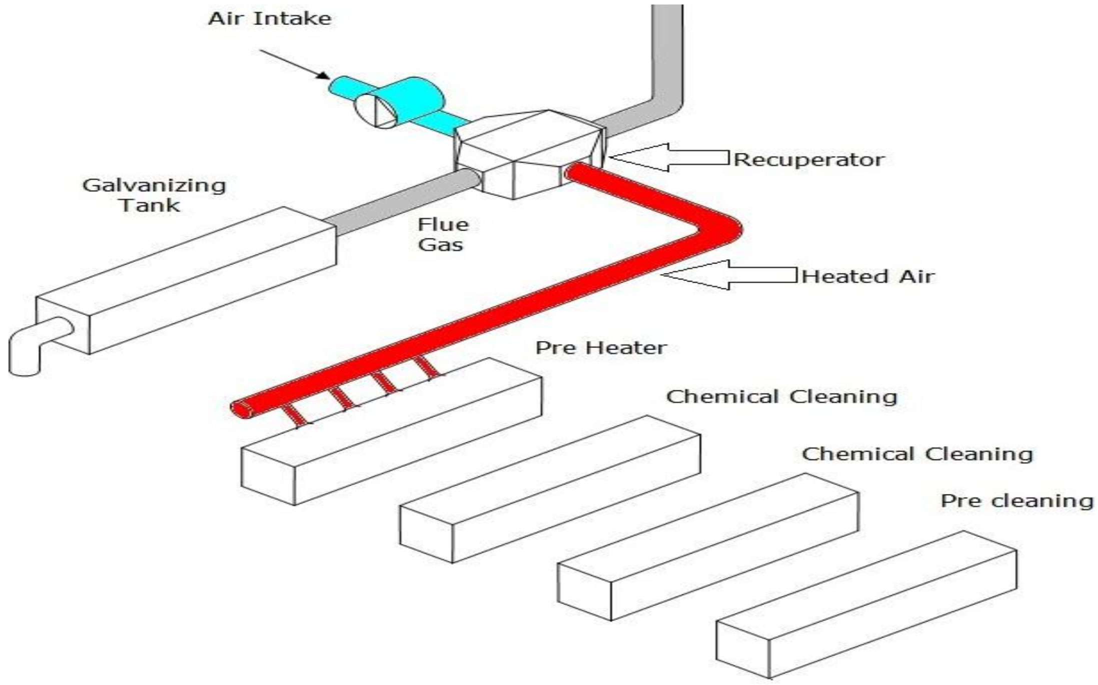

Figure 2. Recuperator applicated Galvanizing Process

By means of the recuperator application, required hot air for the preheating process can be produced from waste heat of flue gas. The flue gas gets in to the recuperator at 350 ^oC and goes out at 150 ^oC temperature. It is expected to reduce inlet temperature of the flue gas about 200 ^oC in the recuperator.

4. Calculations

It can be calculated the flue gas amount from the combustion of natural gas. For this purposes the stoichiometric combustion equations should be used. Fuel analysis is shown on Table 1.

Table 1. Composition of Fuel [6]

Fuel analysis	% Obtained
Methane	94.1
Ethane	0.1
Propane	1.20
Butane	0.12
Pentane	2.71
Nitrogen	1.66
Carbon dioxide	0.11
Total	100

Each mole of oxygen in the combustion air is accompanied by 3,76 moles of nitrogen, which is inert [7].
The combustion equation for the methane is shown below;

$$CH_4 + 2\ O_2 + 7.52\ N_2 \rightarrow\ CO_2 +\ 2H_2O + 7.52\ N_2 \qquad (1)$$

Other combustion gases and required air can be calculated in this way. Calculation of total input and flue gas is given in the Table 2.

Table 2. Combustion Products and Air Requirement for Complete Combustion

	INPUT GASES (Nm^3)			FLUE GAS (Nm^3)		
Fuel Analysis	% Ob	O_2	N_2	CO_2	H_20	N_2
Methane	94,1	1,882	7,07632	0,941	1,882	7,07632
Ethane	0,1	0,0035	0,01316	0,002	0,003	0,01316
Propane	1,2	0,06	0,2256	0,036	0,048	0,2256
Butane	0,12	0,0078	0,029328	0,0048	0,006	0,029328
Pentane	2,71	0,2168	0,815168	0,1355	0,1626	0,815168
Nitrogen	1,66	-	1,66	-	-	1,66
Carbon dioxide	0,11	-	0,11	-	-	0,11
Total	100	2,1701	9,929576	1,1193	2,1016	9,929576
	13,099676			13,150476		

The table indicates that 1 Nm^3 of natural gas in given composition needs 12 Nm^3 of air. The stoichiometric Air/Fuel Ratio (AFR) is 12,099. Under stoichiometric conditions it is impossible to obtain complete combustion. Incomplete combustion leads to the formation of carbon monoxide, an extremely toxic gas, in the products and it is a waste of energy. To obtain complete combustion it is needed to use excess air. For the natural gas excess air ratio is 1,07-1,12 and we used 1,1 for calculations [8]. As the excess air ratio added the flue gas amount reaches to 17,50 Nm^3 for 1 Nm^3 fuel.

It is needed to turn this numbers to the hour based flow rates. The burners have a 42,2 Nm^3/h natural gas flow rate.

Air flow rate; $42,2*14,289 = 602 \text{ Nm}^3/h$

Flue Gas flow rate; $42,2*17,5 = 738,5 \text{ Nm}^3/h$

As recuperator income and outcome temperatures and flow rates are known it is possible to calculate the heat conservation in recuperator. It is required the C_v value of the flue gas.

$$C_v = -2,95*10^{-11}T^3 + 3,45*10^{-08}T^2 + 7,76*10^{-05}T + 0,322757 \quad (2)$$

$C_{V_{350}} = 0,3528$ $\quad$ $C_{V_{150}} = 0,3351$

It will be used the heat equation to calculate amount of heat conserved in the recuperator. In (2) C_v is specific heat and T is temperature. In (3) V_h is flue gas value, C_v is specific heat and T is temperature

$$Q_h = V_h(T_1C_{V1} - T_2C_{V2}) \quad (3)$$

$$= 738,5(350*0,3528 - 150*0,3351)$$

$$Q_h = 54069,2775 \text{ kcal/h}$$

The amount of absorbed energy by recuperator is 54000 kcal/h. Recovered heat energy is equal to 6,54 m^3 of natural gas. This means %15 of natural gas burned in an hour. It can be calculated the monthly recovered energy as 4708 m^3 natural gas equivalent. Monthly natural gas cost for the 42,2 Nm^3 is 18000 TL. After recuperator application monthly income is 28000 TL/h.

5. Results and Conclusion

Recovery of waste heat is very important from the point of efficiency of the process. Recovery of waste heat reduces the fuel consumption that leads to reduction in flue gas amount. Therefore some equipment sizes, which used flue gas handling, can be reduced such as fans, etc. This gives also additional benefits paying attention to energy consumption such as electricity of fans, etc.

Recovery of waste heat reduces environmental pollution as well. It supports sustainable economy and environment.

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