Investigation of Waste Heat Recovery in Cement Industry: A Case Study

N. A. Madlool, R. Saidur, and N. A. Rahim

***Abstract*—In recent years, there has been an increasing interest in waste heat recovery in the cement industry. The aim of this work is to determine the waste heat recovery by utilizing the waste exit gases from the pre-heater and grate cooler to generate electricity, furthermore estimation of cost saving. The results based on the operational data which is collected from Al-Muthanna Cement Plant. The net power output of 834.12 kJ/kg was estimated. A 6.673 ×103 MWh/yr electricity generation were achieved. The cost saving was estimated of 467,110.00 USD/yr in addition to 20 months was expected as the simple payback period.**

***Index Terms*—Energy saving, cost saving, pre-heater, cement industry.**

I. INTRODUCTION

The cement sector is one of the most energy intensive industries. The clinker calcination process is the most energy exhaustive in cement production, because of the exit gases from the clinker cooler and pre-heater at the head and tail of a kiln with temperature lower than 400 ℃ are wasted. As a result to the previously mentioned, the heat losses accounted for more than 30% of thermal consumption for clinker production, which considered large energy amount was wasted. Therefore to reduce both energy consumption and greenhouse gas emission, the waste heat can be recovered for power generation [1].

The energy consumption is ranged from 4 to 5 GJ/tonne of cement was indicated by studies. A share of energy consumption of cement industry in the industrial field is between 12% to 15%. And it represents 2% to 6% of total energy consumption in terms of countries [2].

Continually, to improve energy use profitability and competitiveness, many effectual technologies in energy use by industry were adopted. A significant number of studies have been concentrated on the analysis of energy and its utilization in cement industry. Among them, there are very important and constructive papers. Madlool et al. [3] reviewed the energy use in cement industry. Doheim *et al*. [4] examined the thermal energy consumption, losses and the heat saving potentials. For dry process in cement industry, Engin *et al*. [5] and Kabir *et al*. [6] applied an analysis of energy audit. Khurana *et al*. [7] presented the analysis of thermodynamic and cogeneration. Rasul *et al*. [8] presented the assessment of thermal performance and energy conservation opportunities for cement industry in Indonesia.

Ahmed *et al*. [9] optimized the operational parameters such as masses of cooling air and clinker, cooling air temperature, and grate speed to improve the energy, exergy and recovery efficiencies of a grate cooling system. Using heat recovery from the exhaust air, energy and exergy recovery efficiencies of the cooling system were increased by 21.5% and 9.4%, respectively. About 38.10% and 30.86% energy cost can be saved by changing mass flow rate of clinker and mass flow rate of cooling air, respectively.
Besides these studies, the exergy analysis for complete system in the cement production was demonstrated by Koroneos *et al*. [10]. Whereas, the exergy analysis for cement industries was reviewed by Madlool *et al*. [11].

At the range of temperature of 200 to 300°C, almost 40% of total input of heat is emitted from the exit gases of pre-heater and clinker cooler.

The waste heat is used in different applications, such as drying of raw materials, air preheating which is required for the coal combustion cogeneration [12].

Al-Rabghi *et al*. [13] reviewed the utilization of waste heat recovery in diverse industry sectors. Saneipoor *et al*. [14] studies the performance of a new Marnoch Heat Engine (MHE) in a typical cement plant. Sogut *et al*. [15] examined rotary kiln heat recovery for a cement plant in Turkey. Jiangfeng Wang *et al*. [16] used four kinds of power plant to recover the waste heat from the exit gases of pre-heater and grate cooler in order to generate the power in a cement plant.

This work determines the electrical energy saving which is led to reduction in energy consumption, and thus, reduction in cost saving. As well as, estimation of the simple payback period was accomplished.

II. WASTE HEAT RECOVERY

In addition to the plan of reducing of energy consumption in cement production process, the recovery waste heats can be achieved in order to produce the electrical energy by utilization cogeneration power plant. This means no additional fuel consumption and thus, reducing the high cost of electrical energy and the emissions of greenhouse gases. The waste heats can be classified as waste heats of middle and low temperatures. Some power plants are available and suitable to recover the waste heats [6]. The waste heat sources in the cement plant include the exit gases from the pre-heater and the clinker cooler ejection hot air. And for cogeneration power, these sources which have diverse level of temperature can be used separately or together. The temperature of ejection hot air from the cooler is 220°C and

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the temperature of gases which leave the suspension pre-heater is 325°C. As shown in Fig1, the steam which is generated via WHRSG by utilizing these two sources would be used to drive a steam turbine. A steam turbine will drive the electric generator to produce the electricity. This will reflect in reduction of electricity demand.

The net power of cogeneration power plant was 834.12 kJ/kg. If we consider the operation hours in 1 year is 8000hrs. Then the electric saving will be 6.673×10^3 MWh/year.

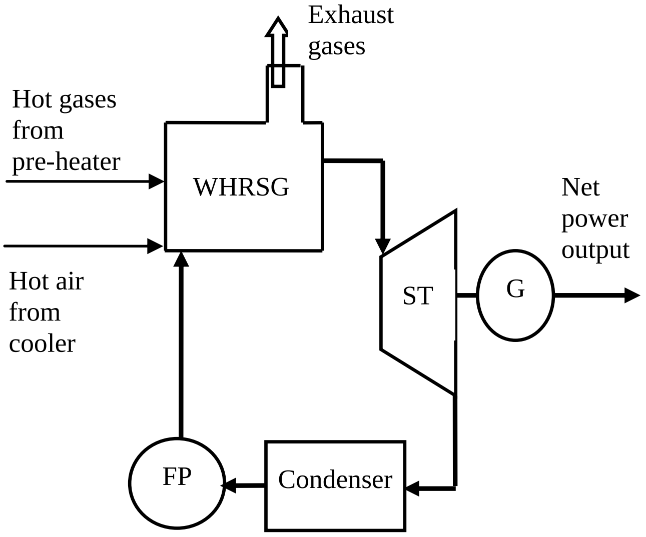

Fig. 1. Cogeneration power system.

III. PERFORMANCE OF WHRSG CYCLE

For the WHRSG cycle, the performance of WHRSG is summarized in Table 1. It is noticed that the plant thermal efficiency was 26.6%, while the efficiency of exergy was 46.8%. The efficiency of exergy can evaluate the performance of cogeneration system.

TABLE I: PERFORMANCE OF COGENERATION SYSTEM

Boiler heat supply (kW)	3241.22
Turbine work (kW)	834.3
Condenser heat rejected (kW)	2594.6
Pump work (kW)	0.17
Net power output (kW)	834.12
Thermal efficiency (%)	25.7
Exergy efficiency (%)	46.83

A comparison for the cycle results were done with Jiangfeng Wang et al. [16], it is found that thermal efficiency and exergy efficiency better than the obtained efficiencies via Jiangfeng Wang et al. [16].

IV. COST SAVING AND PAYBACK PERIOD

Considering the average of electricity unit price can be taken as 0.07 USD/kWh. The expected cost savings can be estimated as following:

Cost saving= energy saving $\times$ energy cost
Cost saving= $(6673\times10^3/2000\times10^3)\times0.07=0.23$ USD/tonne

Due to capital budgeting, the payback period is the required time for the return on an investment to repay the original investment sum. The cost savings was expected of 467,110.00 USD/yr.

If we consider the average costs of maintenance out to 30,000 USD/yr, then the cost savings will become 437,110.00 USD/yr.

Budget estimation together with shipping and installation is 750,000 USD, consequently, a roughly valuation for payback period would be
Payback period = (Cost of implementation cost)/ (Annual cost savings)
Payback period = (750,000.00 USD / 437,110.00 USD/yr) = 1.7 ≈ 20 months.

V. CONCLUSION

The results can be written in some points as following:

1) The net power output was 834.12 kJ/kg and the generated electricity was 6.673×10^3 MWh/yr in cogeneration power plant.
2) The cost saving was 0.233 USD/tonne for the cogeneration power system.
3) Payback period for this system will be roughly 20 months.

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