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Design and analysis of a cogeneration plant using heat recovery of a cement factory

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ABSTRACT

There is a more potential in a cement factory for electric power generation using waste heat recovery compared to the other industries. A case study has been done at a cement factory having two units, 1600 TPD and 5500 TPD, identified three waste heat rejections at 176 °C, 330 °C and 420 °C and designed a suitable power plant configuration. In this work, an attempt has been made to quantify the power generation capacity with plant analysis. It has been resulted that 12.5 MW of power can be produced with the available heat recovery against a cement factory demand of 15 MW. The available process heat for cement production and power generation has been estimated at a capacity range from 5000 to 9000 TPD. The analysis recommended a low steam pressure for power generation at above said heat recovery gas temperature.

1. Introduction

A cogeneration or combined heat and power (CHP) system produces steam that provides thermal energy to heat exchangers and mechanical energy through expansion to turbine units or generation of process heat and power. The turbine units then transfer the mechanical energy to generators, which in turn produce electricity. The principle technical advantage of cogeneration systems is their ability to improve the efficiency of fuel use in production of electrical and thermal energy. Less fuel is required to produce a given amount of electrical and thermal energy in a single cogeneration unit than is needed to generate the same quantities of both types of energy by separate conventional technologies.

Operation of cogeneration plant by generating steam using waste heat recover is a more economic option compared to direct generation of steam which is possible in steel plants and cement factories. There is a more potential in cement factory to generate power due to its increasing demand in building and constructions. Madloola et al. [1] reported that production of cement increased from 2.95 million tons in 1950–1951 to 161.66 million tons in 2006–2007 in India. Cement industry consumes a more amount of energy compared to other industries [2]. The energy consumption for the production of cement is approximately from 4 to 5 GJ/t [3]. Worrell et al. [4] analyzed the historical trends between 1970 and 1997 and reported that carbon dioxide intensity from combustion dropped 25%, from 0.16 tC/t to 0.12 tC/t. Khurana et al. [5] identified that about 35% of the input energy is being lost with the waste heat streams. Rasul et al. [6] stressed that replacing diesel fuel with waste heat recovery from kiln and cooler exhaust for drying of raw meal and fuel, and preheating of combustion air, a cement industry can save about 1.264×10^5 US dollars per year. Utlu et al. [7] suggested waste heat recovery to a cement

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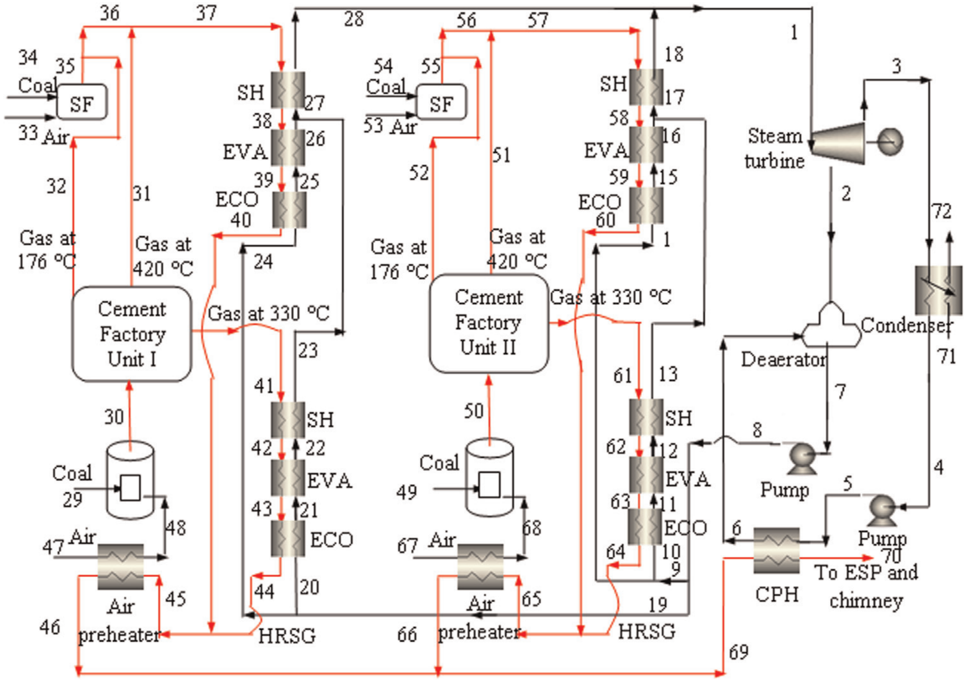

Fig. 1. Cogeneration plant layout for a cement factory with a steam power system, CPH: condensate preheater; ECO: economizer; ESP: electro static precipitator; EVA: evaporator; HRSG: heat recovery steam generator; SF: supplementary firing; and SH: superheater.

plant to increase the energy efficiency of plant. Cogeneration of power besides mitigating the problem of power shortage helps in energy conservation as well as reducing green house gas emissions. Cogeneration systems have been successfully operating in cement plants in India, China and South-east Asian countries. Engin and Ari [8] conducted an energy auditing to a cement factory and suggested a cogeneration proposal. Their economic evaluation showed that the pay back period for the cement plant cogeneration is less than 1.5 years. In existing plants cogeneration technologies based on bottoming cycles have potential to generate up to 25–30% of the power requirement of a plant. Sui et al. [9] calculated the power generation per ton clinker of the waste heat as 30.75 kWh/t.

Indian cement industry is yet to make a beginning for the adoption of cogeneration technology due to existence of various technical and financial barriers. The literature survey shows that many cement industries are not operating on cogeneration mode. The literature is focused on energy auditing, energy and exergy approaches with possible improvements. A detailed power generation system suitable to a cement plant with thermodynamic analysis is not developed and reported. The current work is aimed on the identification of possible heat recovery potential from a cement plant through a case study, design and thermodynamic analysis with a suitable power plant configuration.

2. Methodology

A potential has been identified to generate power from the available heat recoveries has been identified based on the case study of 7100 TPD capacity cement plant. A suitable plant configuration has been designed and shown in Fig. 1 to suit the temperature level and gas stream flow rate. The plant consists of two units having 1600 TPD and 5500 TPD respectively. Coal has been used in the plant's furnace (combustion chamber) for the processing of cement. The details of cement factory are omitted since the focus is given to the cogeneration plant. After the use of hot gases to the cement production processes, three sources are available to generate the steam for power generation. But out of these three sources, one source is at 176 °C which is not suitable for steam generation at the required pressure level. Therefore, supplementary firing (SF) has been used to rise the temperature from 176 °C to 420 °C with suitable selection in coal consumption and gas mix to meet the temperature. After mixing, it became two gas sources at 420 °C and 330 °C to generate the steam at two levels so that four steam lines from the two units. The steam temperature from 330 °C gas source is low compared to the steam temperature from 420 °C. Therefore, the low temperature steam has been mixed to high temperature steam line and superheated to the turbine inlet temperature. The steam from the four lines is mixed and supplied to turbine for power generation. The designed thermal power plant is simple Rankine cycle with a deaerator. After condensing the exhaust steam, it is pumped to deaerator via condensate preheater. The water from the deaerator is pumped to boiler pressure and supplied to four lines with flow control to recover the waste heat. The exhaust gas is used for air preheating and condensate preheating after steam generation. Finally the exhaust gas is treated in electro static precipitator (ESP) and connected to a stack of chimney.