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THERMODYNAMIC STUDY ON COGENERATION SYSTEM IN A CEMENT FACTORY

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ABSTRACT

Production of Cement is one of the most energy intensive industries in the world. In cement plants, clinker and rotary kilns are widely used for raw material production. In the dry process cement plants nearly 40 % of the total heat input is rejected as waste heat from exit gases of preheater and grate cooler. This waste heat can be effectively utilized for electric power generation. Cogeneration of power besides reducing the problem of power shortage also helps in energy conservation as well as reducing green house gas Emissions. Cogeneration systems have been successfully operating in Cement plants in India and Asian Countries. In existing plants cogeneration technologies based on bottoming cycles have potential to generate up to 25-30 %of the power requirement of a plant. However, the Indian cement industry is not utilizing the full potential of Cogeneration due to existence of various technical and financial constraints. An investigation on a cement industry is conducted and noticed that, industry requires 15 MW of power for running the plant. So they are completely depending on APGENCO. One solution that continues to gain profits is to produce their own power using cogeneration. In this paper, using waste heat recovery systems and supplementary firing, around 70-75% of power is supplied to the cement industry. By theoretical approach, for the given input data of the plant, 12.28 MW of power can be produced using cogeneration.

Keywords:* - *cement; cogeneration; supplementary firing; waste heat.

I. INTRODUCTION

The Rising Energy cost in cement manufacture has spurred development efforts towards more effective energy conservation measures. Of late, to contain energy cost as well as make cement manufacture more and more environmentally benign, waste energy management, adopting cogeneration system based on waste heat recovery, is gaining importance. Such a development assumes considerable significance and potential in Indian cement industry in order to achieve cost economy and environmental compatibility. Currently all cement industries are taking aims to upgrade the technology in all sections of production. In addition, vertical roller mills for limestone and coal grinding as well as for clinker and slag grinding, roller presses for limestone, clinker and slag grinding, 6 stage pre heaters and air beam technology for grate cooler, use of high grade fuel in place of low grade 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 with separate, conventional technologies. fuel etc. has enabled drastic reduction in energy consumption and increased productivity. However, the Indian cement industry is yet to make a beginning for the adoption of cogeneration technology due to existence of various technical and financial barriers [1]. A cogeneration or combined heat and power (CHP) system produces steam that provides thermal energy to heat

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exchangers and mechanical energy through expansion to turbine units. The turbine units then transfer the mechanical energy to generators, which in turn produce electricity [2]. World demand for cement was 2283 million tonnes in 2005and China accounted for about 47% of the total demand. It is predicted that the demand will be about 2836 MT in the year 2010. China will increase its demand by 250 million tons during this period. This increase will be higher than the total annual demand for European Union. It was reported that Japan and the US, India is the fourth largest A Cement-producing country in the world. Table 1 shows the annual production of cement for few selected countries around the world [3]. Mandal and Madheswaran [4] reported that production of cement increased from 2.95 million tons in 1950–1951 to 161.66 million tons in 2006–2007 in India. Sharma [5] installed Two Plants in Andhra Pradesh and those Plants are successfully running on Cogeneration Technology. TahsinEngin and Ari [6] reviewed a cement factory, a secondary shell system has been proposed, designed and showed the energy recovery. Schuer et al. [7] gave energy consumption values and described the energy saving methods and potentials for German Cement Industry. The research was based on electrical and thermal energy saving methods. The results were given in the form of energy flow diagram.

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Table1: Global cement production statistics for the year 2005 [16]

Sectors	Production (MT/yr)	Share (%)
China	1064	46.6
India	130	5.70
United States	99	4.30
Japan	66	2.90
Korea	50	2.20
Spain	48	2.10
Russia	45	2.00
Thailand	40	1.80
Brazil	39	1.70
Italy	38	1.70
Turkey	38	1.70
Indonesia	37	1.60
Mexico	36	1.60
Germany	32	1.40
Iran	32	1.40
Egypt	27	1.20
Vietnam	27	1.20
Saudi Arabia	24	1.10
France	20	0.90
Other	392	17.20
World	2284	100

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Shaleen et al. [8] conducted research on energy balance in a cement industry. They used the data from existing plant in India with a production capacity 1MT per annum. The author found that about 35% of the input energy was lost with the waste heat streams. A steam cycle was selected to recover heat from the streams using a waste heat recovery steam generator and it was estimated that about 4.4 MW of electricity could be generated. Madlool et al [9] Reviewed the energy use at different sections of cement industries, specific energy consumption, types of energy use, details of cement manufacturing processes, various energy savings measures were reviewed and suggested different energy saving measures. Zafer Utlu [10] carried out Energy and Exergy analyses of Raw mill and raw material preparation unit in cement plant in Turkey using the actual operational data. Energy and Exergy efficiency are determined to be 84.3% and 25.2%. Sogut et al. [11] conducted a study to assess the performance of a Trass mill in a cement Plant based on the actual Operational data using Energy and Exergy Analyses. Pradeep Kumar [12] stated that power consumption of Indian cement industry is 14 billion units/year. Wang et al. [13] examined the Exergy performance of Kalina cycle system (KCS) and organic Rankine cycle (ORC) plants and concluded that Kalina cycle can achieve the best performance from the view point of exergy efficiency and the ORC shows the lowest exergy efficiency under the same conditions. Ramesh et al. [14] carried out an energy audit of thermal utilities in a cement plant at Karnataka. A waste heat recovery steam generation system was selected showing the energy saving potential of 1.14 MW from the waste heat streams. Khattak et al. [15] conducted only case study without a detailed thermodynamic analysis.

II. METHODOLOGY

A typical 15 MW (before Cogeneration) cement plant in Andhra Pradesh was selected as the case study as shown in fig:1 shows the flow of various streams and components of the plant. Plant runs on dry process with 6 stage preheater and a calciner. The production capacity is 1600 TPD and 5500 TPD from both the kilns. It is the pyroprocessing unit that includes the preheater, calciner,kiln and the grate cooler. The streams into the system are the raw material, air into the cooler and the coal fired into the kiln and the calciner. The streams leaving the system are clinker out from the cooler, the exhaust gas from the preheater and the hot air out from the cooler. In the preheater, the raw meal undergoes a series of concurrent heat exchanges with the hot exhaust gas from the kiln system. The gas and the material stream are separated by cyclones, after each heat exchange process. The raw meal temperature increases from 80 ^{0}C to 1000 ^{0}C within 40 seconds. The calcinated material entering the kiln, then undergoes a long heating process.The material temperature rises from 1000^{0}C to1450^{0}C. Mineral matrixes of raw material are totally destroyed and cement minerals are formed at the sintering temperatures. A semi product called clinker is formed. Coal and other alternate fuels are used as energy sources for the process. The ash fromfuels is absorbed into the clinker matrix. The residual heat from the clinker leaving the kiln is recovered by grate cooler to reduce the energy requirement. The clinker cooler cools the hot granular mass by quenching air into it bringing temperature down to <110^{0}C. So air become hot and clinker cold. This hot air is then utilized as combustion air for the firing system of the kiln. The relevant data is collected from a cement factory in Andhra Pradesh. The requirement of the plant is 15 MW. Hence, a target of 15 MW power from waste heat recovery system to be explored. Possibility of increasing the power by additional fuel firing (coal/gas/oil/other fuels) can also be explored.Considering necessary data, preheater gas at 1.6Nm³/KgCl at 330^{0}C and cooling down to 226^{0}C, Taking mid air takeoff of 0.7 kg/kgCl at 420^{0}C. Balance gas at cooler vent (after mid tap) 0.55 kg/kgCl at 176 ^{0}C will be heated up to 420 ^{0}C by using HAG and the mixed gas(0.7+0.55 = 1.25 lg/kgCl at 420 ^{0}C) will be fed to the cooler boiler. Necessary pre duster to reduce the dust content in the cooler gas will be used. The combined cooler gas will be cooled to maximum possible limit. The steam from preheater will be routed through the final superheater in the cooler boiler and the

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superheated steam will be expanded into the turbine. The above points are common for both the lines. To calculate the gas volume, 1600 TPD for line 1 and 5500 TPD for line 2, will be considered as Kiln operating capacity as provided. The steam from both the lines will be fed into a common turbine. Balance of plant will be common for both the lines. Individual boiler considered for each line to ensure easy operation of pyro system. In addition to above an optional boiler at raw mill baghouse has been considered. All the baghouse gases will be tapped after baghouse but before fan and this gas will be heated upto 330^{0}C with a dedicated HAG.

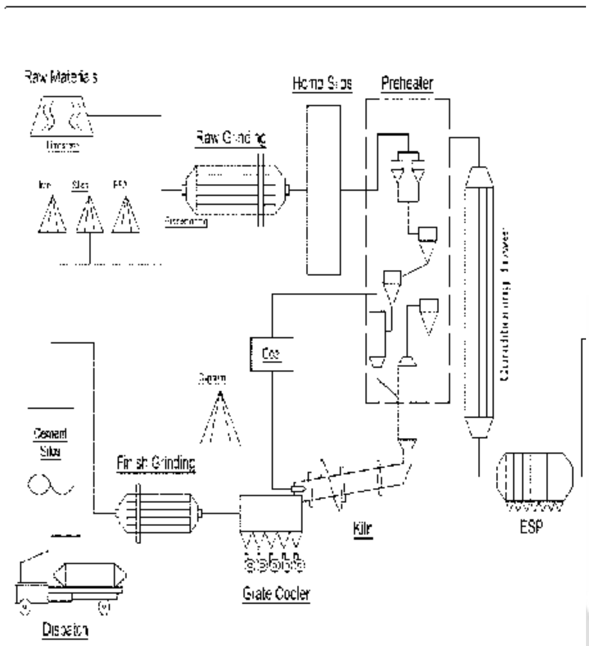

Fig 1 Schematic Layout of the Cement Factory

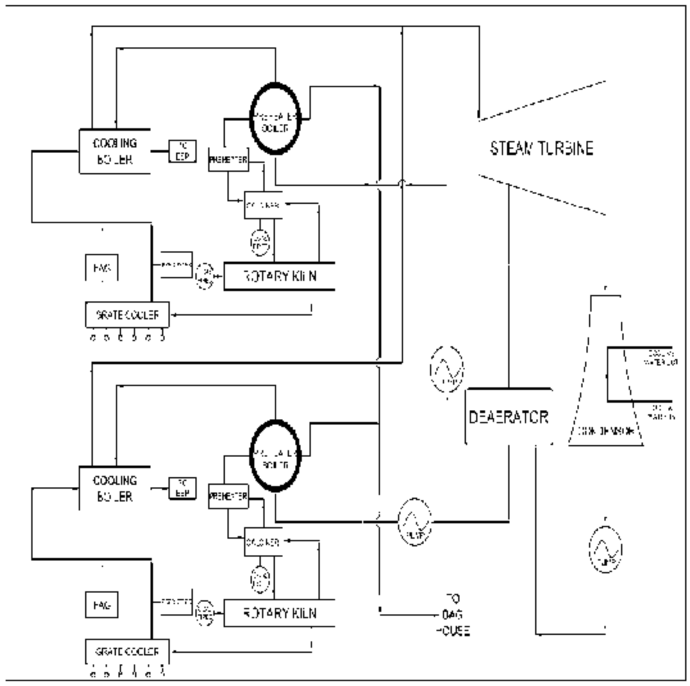

Fig.2 Thermodynamic Modeling and Analysis of Cogen Cement Plant

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III. SAMPLE CALCULATIONS

Heat lost by the flue gases = Heat gained by the water which is converted into the steam
Mass of flue gases in kg/h = (Molecular weight of gas x Flow rate in Nm^3/h)/ 22.4

$m_f \times c_p \times \Delta T = ms_1 \times (h_2 - h_1)$

Mass of steam from kiln1 = 13.736×10^3 kg/h

$m_f \times c_p \times \Delta T = ms_2 \times (h_2 - h_1)$

Mass of steam from kiln2 = 47.2175×10^3 kg/h
Mass of steam striking the turbine M_S = Mass of steam from kiln1 (ms_1) + Mass of steam from kiln2 (ms_2)
Work done by the turbine = m (h – h) kJ/
Total power generated = 12.278 MW

IV. RESULTS

The rate of flue gases from the preheater and the grate cooler are utilized by the preheater boiler and cooler boiler and it is summarized in the table 2 shown below.

Sl.No	Parameters	Kiln-1	Kiln-2
1.	Operating capacity in TPD	1600	5500
2.	Flue gas flow rate from Preheater at 1.6 Nm^3/h	106.66×10^3	366.66×10^3
3.	Flue gas flow rate from cooler vent side in kg/h	83.33×10^3	286.45×10^3
4.	Specific Heat of flue gases in kJ/kgK	0.24	0.24
5.	Steam rate from preheater boiler in kg/h	7572.69	25030.04
6.	Enthalpy of superheated steam from preheater boiler 16 bar & 305 ^{0}C kJ/kg	3047.25	3047.25
7.	Enthalpy of steam exhaust preheater boiler at 35 ^{0}C	2565.4	2565.4
8.	Steam rate from cooler boiler in kg/h	13.736×10^3	47.2175×10^3
9.	Enthalpy of superheated steam from cooler boiler at 15 bar & 390 ˚C	3235.02	3235.02
10.	Enthalpy of cooler boiler at 35 ˚C	2575.4	2575.4

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V. CONCLUSIONS

As the plant requires 15 MW of power which is purchased from APGENCO can be completely produced inside the plant using the waste heat from preheater gases and cooler vent gases. The steam from the preheater boiler will be routed through the final super heater in the cooler boiler and the superheated steam will be expanded in the turbine. From the theoretical calculations it is observed that a total power of 12.28 MW can be produced by the plant itself when considering the condenser operating pressure at 0.4 bar, 12.28 MW of power can be produced. Additionally the industry requires 2.72 MW of power to run the plant. So solar power is utilized to generate the additional 2.72 MW of power. Finally, using cogeneration the waste heat can be effectively utilized to generate power as large amounts of heat are simply released to the atmosphere resulting in global warming. Hence, using these waste heat large amounts of power can be generated keeping the environment safe from radiation and global warming.

REFERENCES

[1] Cogeneration of Power Utilising Waste Heat in Cement Manufacture : Technological Perspectives ; 7th NCB International Seminar on cement and Building Materials New Delhi,21-24 November 2000

[2] D.J. Marshman , T. Chmelyk , M.S. Sidhu , R.B. Gopaluni , G.A. Dumont ; Energy Optimization In A Pulp And Paper Mill Cogeneration Facility ; Applied Energy 87 (2010) 3514–3525

[3] N.A. Madlool, R. Saidura, N.A. Rahimb, M.R. Islama, M.S. Hossianb ; A critical review on energy use and savings in the cement industries ;Renewable and Susttainable Energy Reviews 15(2011) 2042-2060

[4] Mandal .S and Madheswaran.S Environmental Effiency of the Indian Cement Industry:an interstate analysis , Energy Policy 2010;38;1108-18.

[5] R.A.Sharma,Co-Generation & Success Story In Indian Cement Industry

[6] Tahsin Engin,Vedat Ari 2004 “Energy auditing and recovery for dry type cement rotary kiln systems—A case study”, Energy conservation and management2005(551-562)

[7] Schuer, A., Leian, A., and Ellerbock H .G. 1992. “Possible Ways of Saving Energy in Cement Production,Cement Gips”, pp-175-182

[8] Shaleen Khurana, Rangan Banerjee, Uday Gaitonde 2002.”Energy balance and cogeneration of cement plant”Applied Thermal Engineering Vol.22, pp.485-494

[9] N.A. Madlool, R. Saidura, N.A. Rahimb, M.R. Islama, M.S. Hossianb ; An Exergy analysis for cement industries: An overview ; Renewable and Sustainable Energy Reviews 16 (2012) 921– 932

[10] Zafer Utlu , Ziya Sogut , Arif Hepbasli , Zuhal Oktay ; Energy and exergy analyses of a raw mill in a cement production; Applied Thermal Engineering 26 (2006) 2479–2489

[11] M.Z. Sogut , Z. Oktay , A. Hepbasli ; Energetic and Exergetic assessment of a Trass mill process in a cement plant; Energy Conversion and Management 50 (2009) 2316–2323

[12] Pradeep Kumar General Manager National Council for Cement and Building Materials; Power Point Presentation on Cogeneration of Power Through Waste Heat Recovery in Cement Plants

[13] A. Ramesh, Leo. A. J & G. Madhu 2013; Energy audit of thermal utilities in a cement plant; IJME Vol. 2, Issue 2, May 2013, 11-22

[14] Zulfiqar Khattak1, Jamil Ahmad Khan, Aasar hmad, Sifat Shah,Sheryar Masaud; Cogeneration of power through waste heat recovery, ICFEPES2012.

ISSN 2395-3594