Journal of New Technology and Materials (JNTM)
J. New Technol. Mater.
Special Issue, Vol. 08, N°03 (2019)82-86

OEB Univ. Publish.Co.

AspenPlus based simulation for waste heat recovery in cement industries

Y. Redjeb[a*], K. Kaabeche-Djerafi[a,b] and O. Saouli[a,b]

[a]*Department of process engineering, National Polytechnic School of Constantine, Algeria.*

[b]*Process Engineering Laboratory for Sustainable Development and Health Products, National Polytechnic School of Constantine, Algeria.*

*Corresponding author, email: youcef.redjeb@enp-constantine.dz

Selected paper of JSSE'18, received in final form: March 4, 2019 ; accepted date: March 23, 2019

Abstract

Cement manufacturing is a highly energy intensive process, which resulting a large loss of energy at the level of the different plants, in other way the loss of energy in the form of heat is very significantly at the level of the cooler. This work focus on direct waste heat recovery, where tertiary air was recovered to the preheater, for this study a process model of the preheater, the kiln, and the cooler is developed, using Aspen Plus simulation software, and the model is verified against measured data from industry. This paper presents the influence of the recovery of the waste heat and the natural gas feed on the clinker production and the energy consumption. Results show that the recovery of the tertiary air make the clinker production rise by about 30% and the energy consumption reduced by about 20%. The variation of the flow input value of the natural gas resulted in a positive relationship between natural gas flow and clinker production, and an inverse relationship between the natural gas feed and energy consumption. In the other hand the increase of the natural gas flow resulting an augmentation in the clinker production, and the reverse results for the consumption of energy.

Keywords: waste; heat; simulation; energy; cement; clinker.

1. Introduction

The production of clinker in the cement industries is an energy intensive process, so one ton of clinker production requires approximately 3.2 to 6.3 GJ [1]. This makes energy costs 60% of the production costs, the modern cement production processes basically include the Preheater, the kiln, and the cooler, which are the principal resource of waste heat, the preheater tower is the home of calcination, that mean the decomposition of calcium carbonate ($CaCO3$) with a chemical reaction to leave Calcium oxide (Cao, lime), and liberate the Carbon dioxide ($CO2$), this reaction need about 850°C, the required thermal energy in the preheater is about 60 % of the total thermal energy requirement. The principal goal of the kiln is to augment the temperature of the clinker to about 1500°C, and this require about 20 % of total thermal energy requirement, after the kiln the clinker enter in the cooler to reduce their temperature and cool them which produce the waste heat.

Research on waste heat recovery was initiated several years ago, with a goal to reduce the energy consumption and switch to the green industries, many of systems and integrations have emerged to be applied in many industries plants, including simple systems like heat pump integration [2]. Composite systems including thermodynamic cycles and other systems which gather some modifications [3]. The most direct prominent applications of these systems are the industries that require high temperature in its production, such as iron conversion plants, cement manufacturing and others, because the waste energy in the different installations of these factories are large compared to other small industries, so in this study which focuses on cement production in order to reduce the costs of energy consummation, numerous approaches are going on to build computer process model to recovery the waste heat from the cooler [4]. The most of the approaches are studying the cogeneration of the power from the waste heat with application direct of the applied thermodynamic cycles, including Kalina cycle and Organic Rankine Cycle [5]. There are other approaches that studying the direct recovery of the waste heat from the cooler to the other installations, such as the preheater and the kiln [6]. In this work the study based on the direct recovery of waste heat from the cooler to the home of the calcination.

2. Waste heat recovery

With global changes and the transition to green industries, energy audits have been introduced as one of the most effective energy management measures. With a principal goal is to rationalize significant waste of energy and reducing consumption. Thus, many uses of waste heat in cement industries have emerged after recovering it, either in the electric field or through the integration into its plants [7].

In the process of cement manufacturing, the principal source of waste heat is the cooler, the clinker enter the cooler with a temperature about 1450 °C and then exit from it with a variable and decreasing temperatures [8], so there is a lot of waste heat which classified into tow type of air; secondary air and tertiary air, the first one with temperature about 900 °C recuperate directly to kiln, and the second one is a waste heat with about 100 °C, which recuperate directly to the Calciner.

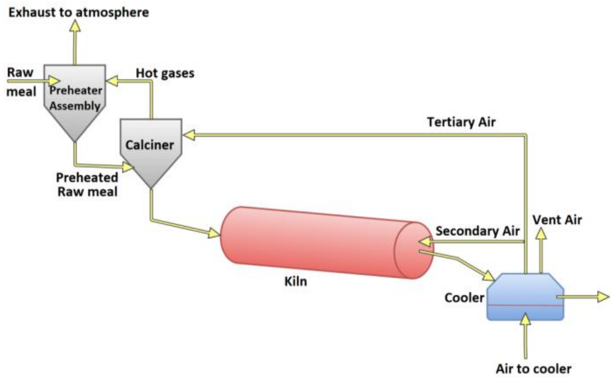

Figure 1. Preheater, kiln, and cooler equipment in cement industry

In this work, the equipment shown in the Figure 1 will be modelled and simulated; focusing on the recovery of the tertiary air, and its impact on clinker production and energy consumption, on the other hand the effect of changing the flow of natural gas on each will be studied.

3. Model development and validation

Several models have been proposed for the recovery of the waste heat in the cement plants, including the direct recovery of the waste heat to the preheater, or converting it into electrical energy, using Kalina cycle or Organic Rankin cycle [9]. All of them take a name WRH that meaning waste heat recovery System, in this work the first model is taken, that was the direct recovery of waste heat including a study of the effect of changing the inputs on energy consumption and production. Additional to plant data, the choice of the different equipment was based on several researches on cement plant modeling [10]. The figure 2 shows the preheater, the kiln, and the cooler flow sheets in Aspen Plus, for the preheater we chose system combine by three cyclones and two separators and a Gibbs reactor; the choice of the Gibbs reactor was aimed at achieving the chemical reaction, represented by calcination, for the kiln a system combine by two colons was chosen, and for the cooler we chose 10 floors everyone contain a cooler colon.

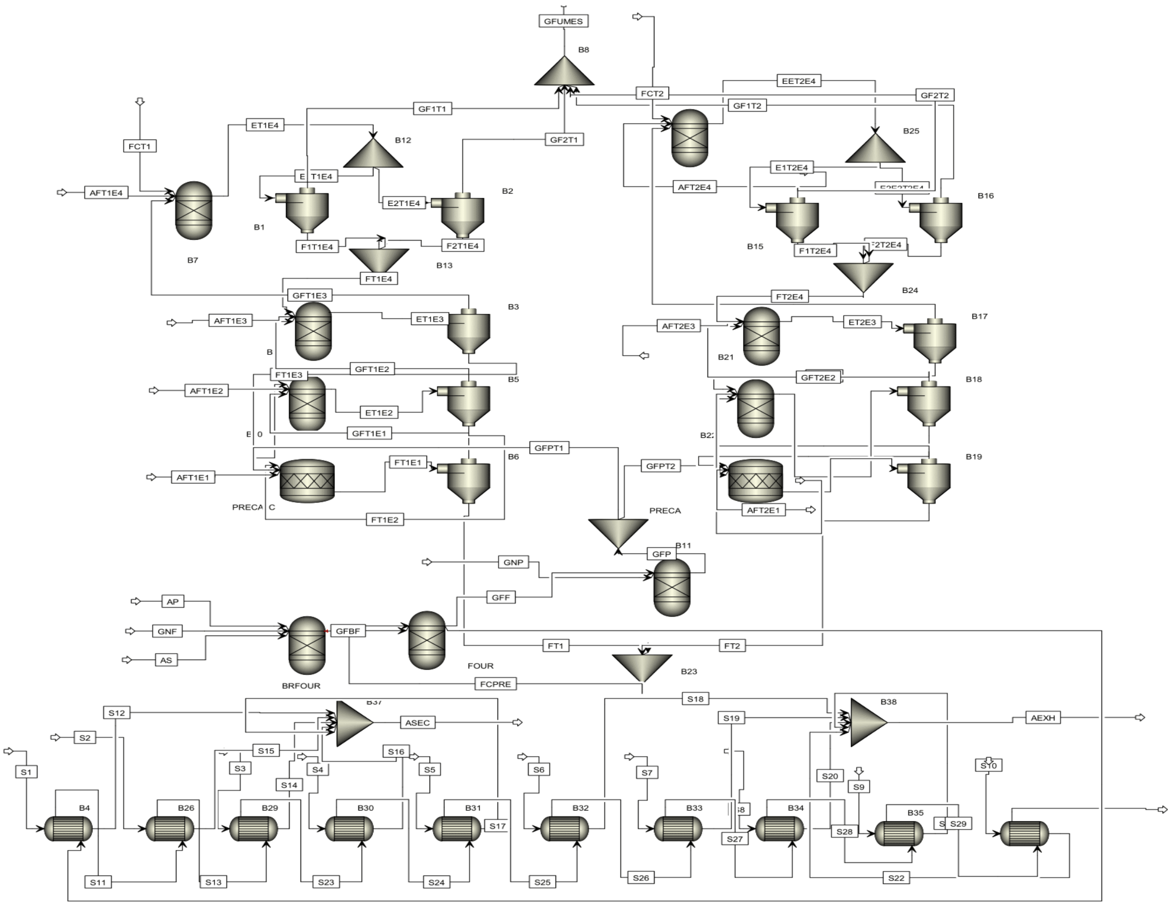

Figure 2. Preheater, kiln, and cooler flow sheets in Aspen Plus

The model was validated by comparing the simulation results with the local results in the cement factory without changing the entries or studying their effect on energy consumption and production. And without tertiary Air recovery, Table 1, 2 and 3 represents the results in both the simulation and cement plant. Comparison of results indicates that the simulations results vary within ±2-10% of plant data, with an exception in the case of total heat consumption which is due to high loss of the heat in the cement plants.

Table 1. Comparison of flow results in simulation and plant data

	Flow (kg/h)	
	Cement	Simulation
Clinker	123900	125236
Gas fume	363966	372224
Secondary Air	157834.08	147149
Air exhaust	235318	244940

Table 2. Comparison of heat results in simulation and plant data

	Heat ($Kcal/Kg_{KK}$)	
	Cement	Simulation
Total	1001.57	832.8
Secondary Air	333.23	281.87
Air exhaust	49.27	45.09

Table 3. Comparison of fraction results in simulation and plant data

	Fraction (%)	
	Cement	Simulation
C_3S	71.24	69.2308
CO_2	19.89	17.5143
N_2	67	65.4696
O_2	3.6	8.2371
H_2O	4.63	8.7324

4. Simulation results and discussion

An aspen plus model for the cement industry was built and verified by plant data, the principal role of this model is to build an integrated process for waste heat recovery, and the study of the influence of different parameters with a but is the optimization of clinker production and energy consumption.

For waste heat recovering, a power mixer was added to the simulation model with a principal task regroup the energy resources from the cooler floors and connect them to the preheating tower. In the same model used, this was studied and simulated with a change in natural gas feed in two steps; without change of the natural gas feed, up and reduce the natural gas feed.

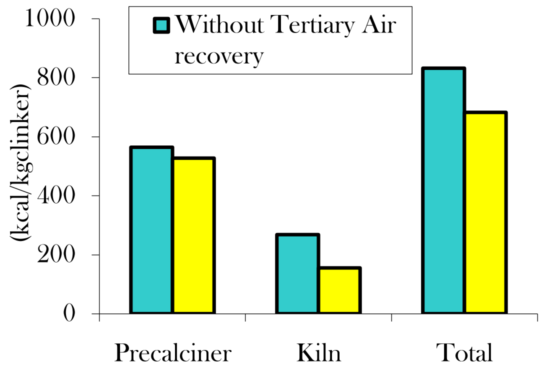

Figure 3. Heat consumption with and without tertiary air recovery

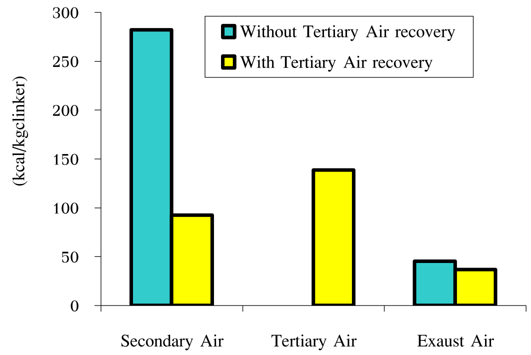

Figure 4. Heat consumption with and without tertiary air recovery

The figure 5 presents the influence of the waste heat recovery on the clinker production, where the simulation was performed in two phases: with and without tertiary air recovery. Clinker production rises by about 30% when tertiary air was recovered compared without recovering it.

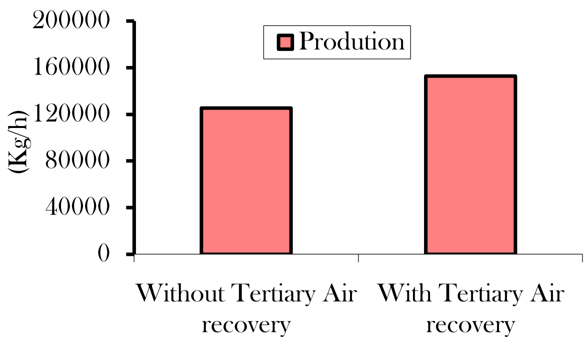

Figure 5. Clinker production with and without tertiary air recovery

The results of the first step suggest that heat consumption of the preheater and the kiln has decreased because of the recovery of tertiary air with a considerable amount of heat, this is the objective envisaged by the recovery of energy, and the amount of secondary air heat after energy recovery is decreased because much of this heat is considered tertiary air. This indicates that the recovery of air has achieved very positive results both on energy consumption or clinker production.

The other phase of this study is to follow up the influence of the natural gas feed on the clinker production, and the heat consumption, by changing the feed input of the natural gas on the flow sheet in Aspen plus software. This step results from simulation have been presented in Figure 6 and 7. It was found from both cases that up the gas feed and down it. The figure 6 presents the influence of increasing and decreasing natural gas feed on the heat consumption, with tertiary air recovery.

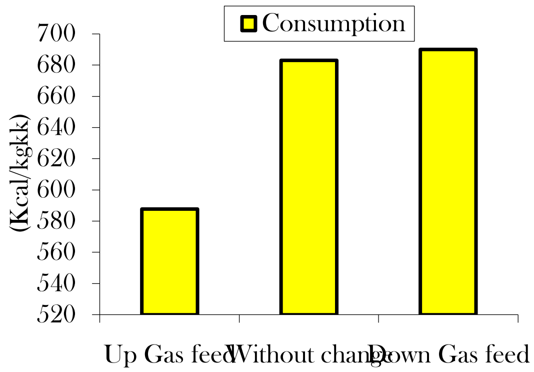

Figure 6. Comparison of heat consumption with up and down and without natural gas feed change

Comparison of heat consumption results indicate that the total heat consumption was reduced by about 20%. And the clinker production was augmented with about 35% when the gas feed increase, and the reverse when the gas feed decreased. That suggests that the influence of the changing of the gas feed is inversely proportional with heat consumption in the cement industry.

The figure 7 presents the influence of increasing and decreasing of natural gas feed on the clinker production, with a done condition tertiary air recovery.

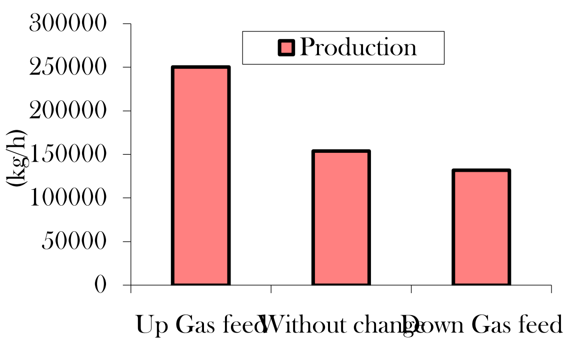

Figure 7. Comparison of clinker production with up and down and without natural gas feed change

There is a positive Relationship between the augmentation of gas feed and clinker production, as opposed the consumption, so if the gas feed is up the consumption decreases and the production increase, and the opposite of that is true.

5. Conclusion

This study focused on tertiary air recovery and natural gas feed changing to optimize the clinker production in cement plant, Process engineering software Aspen Plus was used to build a model for the preheater tower, the kiln, and the cooler to simulate the operating condition and study effect of waste heat recovery and natural gas feed on production and heat consumption. A model was validated by comparing the simulation results and industry data. The results obtained from this study suggest that the recovery of the tertiary air increase the clinker production with about 30 % and decrease the heat consumption with about 20%, as also suggest that the clinker production increase by the augmentation of the natural gas feed, and at the same time the consumption reduce, and the reverse is true when the natural gas feed decrease. That was concluded that the recovery of the tertiary air has a very positive effect on both production and consumption, and increasing the natural gas flow works to optimize the production and reduce energy consumption. The model presented in this study is proved to be a useful tool for determining the influence of different parameters in cement industry.

References

[1] H. G. Van Oss, A. C. Padovani, Cement Manufacture and The Environment, Part II: Environmental Challenges and Opportunities, Journal of Industrial Ecology, 7 (2003) 93-126.

[2] P. Y. Liew, T. G. Walmsley, Heat pump integration for total site waste heat recovery, Chemical Engineering Transactions, 52 (2016) 817-822.

[3] I. G. Steven, F. G. Ramon, C. C. Jose, I. G. Denis, A review of thermodynamic cycles used in low temperature recovery systems over the last two years, Renewable and Sustainable Energy Reviews, 81 (2018) 760-767.

[4] R. Azad, M. G. Rasul, M. M. K. Khan, S. Sharma, Aspen Plus based simulation for energy recovery from waste to utilize in cement plant preheater tower, Energy Procedia, 61 (2014) 922-927.

[5] G.V.P. Varma, T. Srinivas, Power generation from low temperature heat recovery, Renewable and Sustainable Energy Reviews, 75 (2017) 402-414.

[6] K. D. Khatima, K. Mokhtar, S. Ghernoug, B. Abdelber, B. Salim, Energy recovery in the baking line of the cement plant djawadtaher of

Algeria, Chemical Engineering Transactions, 37 (2014) 739-744 DOI: 10.3303/CET1437124.

[7] T. Yuting, L. Xun, Z. Li, L. Hailong, Y. Jinyue, Y. Zhixin, Study on Utilization of Waste Heat in Cement Plant, Energy Procedia, 61 (2014) 455-458.

[8] Documentation cement, Edition, Optimization Workshop baking and heat balance of the rotary kiln with grate coolers and balloons (2012).

[9] K. Matsuda, Low heat power generation system, Chemical Engineering Transactions, 35 (2013) 223-228.

[10] S. M. Kaustubh, K. V. Ganesh, B. K. Sarita, V.R. Vivek, Rotary Cement Kiln Simulator (RoCKS): Integrated modeling of pre-heater, calciner, kiln and clinker cooler, Chemical Engineering Science, 62 (2007) 2590-2607.