International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 24 (2017) pp. 14760-14763


# Process Integration using Pinch Analysis: A Cement Industry Case Study

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**Abstract**

Cement is the primary concern for any construction industry. The 40% of total cost of production in any cement industry is the energy requirement. In India, cement manufacturing process consumes about 15-20% energy among all the energy consuming industries. By the improvement in the process of cement production a lot of energy and capital cost can be saved. To achieve this the Process integration is one of the best way and it is applied to one of the cement plant in central India. In this work a cement plant in central India of 8760 h per year of the total operating hours to produce 1.49 Mt of clinker is considered. As a result of Process Integration it is found out that there is a huge potential to improve the energy savings by waste heat recovery. This work helps the cement plant to find out the energy saving potential in cement plant operation and the process optimization.

## INTRODUCTION

Energy is without a doubt one of the significant items for surveying the warm execution of any cement industry .The cement is an energy serious industry with energy ordinarily representing 30– 40% of the generation costs. The high energy utilization puts the division to an essential position from financial perspective. Energy proficiency change in cement industry is in this way an essential territory of research. A proper strategy for warm execution examination must be embraced to accomplish the main targets, for example, expanding the plant efficiency; limiting the crude material; limiting the energy utilization, and enhancing the execution at fractional load, of any cement industry.

The imperatives i.e. the nature of items and fuel, and keeping up of the temperature of the fumes gas of the furnace (kiln) at a set level, must be considered to accomplish these goals. The item quality relies upon different parameters, for example, coal and raw material qualities, combusting air amount and air extinguishing framework, and so on. The goals could be accomplished by streamlining the energy utilization of the production process in the plant. (1)

To achieve the objective the First and second law of Thermodynamics plays important role in plant operation by applying the input-output energy parameters. By obtaining required information from sensors situated at particular purpose of the furnace and thinking about of the different synthetic responses and the course of energy streams, the optimization of energy system can be done.

Process integration causes industry to moderate energy and material. Thoughtfully Process integration is a term in compound building which implies an all-encompassing way to deal with process outline which considers the collaborations between various unit operations from the beginning, as opposed to upgrading them independently. This can likewise be called integrated process design (Smith)

Process integration is an all-encompassing way to deal with process configuration, retrofitting, and operation of production plants, with applications concentrated on asset protection, contamination avoidance and energy administration. Process integration has just profoundly affected the substance process enterprises, as Pinch analysis and heat-exchanger-network advancement. Notwithstanding, it has erroneously been deciphered as Heat Integration by many individuals, presumably because of the way that heat recuperation ponders motivated by Pinch Concept started this field and still remains the focal piece of Process Integration. PI is worried to the propelled administration of material, energy and data streams in a generation plant and the encompassing group in light of the multi criteria improvement of the processing frameworks.(1)

Pinch Analysis and Exergy analysis are the basic approaches that can be utilize for improving the energy efficiency of industrial processes. (A. Ghannadzadeh)Pinch Technology provides an organised approach for energy saving in processes and whole sites. The technique depends on thermodynamic standards.

The energy and material balance is the primary step for the Pinch analysis. This method utilizes to bring appropriate optimum changes in the process that can results in energy savings. The key focal points of pinch innovation over customary design strategies are its capacity to set an energy focus before the commencement of the design.

The preceding studies showed in the literature attentive on energy and exergy analysis of cement production process. In this study, the process integration with Pinch Analysis of a cement production unit in a cement plant in Madhya Pradesh, India were performed for estimating the performance of the plant with the actual plant working data. The production capacity of the plant is about 4000tonn/day. The production process used for the production of cement is based on dry basis with 5 stage of preheating.

## CEMENT PRODUCTION PROCESS

Production of Cement is exceptionally vitality escalated and includes the synthetic mix of Calcium carbonates (limestone), silica, alumina and little measures of different materials, which are artificially adjusted through extraordinary warmth to shape a compound with restricting properties. The primary strides in Cement production examined are represented in Fig. 1. These steps comprise mainly raw materials preparation, clinker production and finish grinding. [S. Boldyryev et al; 2016]

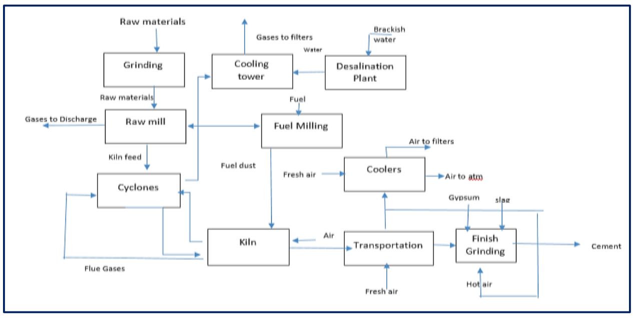


**Figure 1:** Cement Production Process
[S. Boldyryev et al; 2016]

### Raw materials preparation

Raw materials, including limestone, chalk, and earth, are mined or quarried, ordinarily at a site near the cement production plant to reduce the transportation cost. These materials are then ground to a fine powder in the best possible extents required for the cement production. These can be ground as a dry blend or mix with water to shape slurry. The expansion of water at this stage has imperative ramifications for the generation procedure and for the vitality requests amid creation. Generation is regularly ordered as dry process and wet process. In other hand water water is removed and the process is called dry process.

### Clinker production

The blend of raw materials enters the clinker production process. Amid this stage, the blend is gone through an oven (and conceivably a preheated framework) and presented to progressively extreme warmth, up to 1400˚C. This procedure drives off all dampness, separates carbon dioxide from calcium carbonate, and changes the raw materials into new mixes. The yield from this procedure, called clinker, must be cooled quickly to counteract assist concoction changes. Clinker generation is the most vitality escalated step, representing around 80% of the vitality utilized as a part of concrete creation. Created by consuming a blend of materials, fundamentally limestone ($CaCO_3$), silicon oxides ($SiO_2$), aluminum, and iron oxides, clinker is made by one of two generation forms: wet or dry; these terms allude to the granulating forms albeit different arrangements and blended structures (semi-wet, semi-dry) exist for the two sorts. In the wet procedure, the smashed and proportioned materials are ground with water, blended, and bolstered into the furnace as slurry.(2) In the dry procedure, the crude materials are ground, blended, and sustained into the oven in their dry state. The decision among various procedures is directed by the qualities and accessibility of crude materials. For instance, a wet procedure might be important for crude materials with high dampness content (more noteworthy than 15%) or for specific chalks and amalgams that can best be handled as a slurry. Notwithstanding, the dry procedure is the more present day and vitality effective setup.

The grounded materials are bolstered into a furnace for Heating. In present day, the crude material is preheated (in 4–5 phases) utilizing the not utilized heat of the furnace, or it is precalcined. Amid the consuming or pyro-processing, the water is first dissipated after which the substance creation is changed, and an incomplete dissolve is delivered. The strong material and the incomplete dissolve join into little marble-sized pellets called clinker.

### Finish grinding

Cooled clinker is mixed by concurrent crushing and blending with added substances (e.g., gypsum, anhydrite, pozzolana, fly-powder or impact heater slags) to generate the cement. Drying of the added substances might be required at this stage. Cement is an inorganic, non-metallic substance with water driven restricting properties, and is utilized as a holding specialist in building materials. It is a fine powder, generally dim in shading, which comprises of a blend of the pressure driven concrete minerals to which at least one types of calcium sulfate have been included [2]. Blended with water it shapes a glue, which solidifies because of development of bond mineral hydrates. Bond is the coupling operator in solid, which is a blend of concrete, mineral totals and water. Concrete is a key building material for an assortment of utilizations.

## METHODOLOGY

The methodology adopted for the study is based on the study done by S. Boldyryev et al; 2016. Firstly Linnhoff et al. (1994) developed the flowsheet for Pinch analysis and other researchers follow the same for further development. In this work the Hint Software along with the flow sheet developed by Ian C Kemp in there publication used for Pinch Analysis. Hint is a free piece of scholastic software for heat exchanger network design based on the pinch method [Angel Martın]

### Data extraction and energy targeting

The initial step for Process integration utilizing Pinch Technology is information collection which is importance to the Pinch examination i.e. information identified with sources and sinks and the connection between them alongside general process.

The mass balance using laws of thermodynamics has been performed for each streams. The process involved is to find out the process streams in the process that required to be heated and another that required to be cooled. The stream flow rate, thermal properties involving phase and temperatures changes data are collected from the plant operation. The process flow diagram shows the above information.

The enthalpy change rate for all stream is calculated using the relationship [Ian C Kemp]

$$\Delta H = mC_p\Delta T = CP\Delta T \qquad \text{…………… (1)}$$

Where, $\Delta H$ is the enthalpy change rate, $m$ the mass flow rate, $Cp$ the heat capacity, $\Delta T$ the temperature change in the stream, and $CP$ the heat capacity flow rate defined as the product of $mCp$.

### Case Study

A cement plant based on dry process have been considered for the study with 4100 ton per day production capacity. The following data has been extracted while examine the process of cement production.

**Table 1:** Stream Information extracted from the Cement Production Process

| Stream Name | Supply Temperature | Target Temperature | Heat Capacity Flow rate |
|---|---|---|---|
| | °C | °C | kW/K |
| Flue Gas Supply for Milling Raw | 270 | 55 | 21.814 |
| Flue gases Outlet from the kiln | 1000 | 280 | 66.946 |
| Flue Gases for cooling | 280 | 110 | 19.085 |
| Flue Gases to fuel mill | 280 | 90 | 1.193 |
| Clinker after kiln | 1400 | 100 | 24.510 |
| Hot air to coolers | 290 | 100 | 114.839 |
| Air heating to grinding | 270 | 105 | 14.053 |
| Raw material for milling | 30 | 100 | 68.008 |
| Kiln feed | 280 | 810 | 35.033 |
| Hot meal | 810 | 1400 | 34.625 |
| Fuel to Fuel Mill | 30 | 90 | 5.147 |
| Coal dust to kiln | 90 | 150 | 2.860 |
| Air to Kiln | 30 | 150 | 62.305 |
| Air for Clinker Cooling | 30 | 290 | 128.564 |
| Clinker to cement grinding | 30 | 90 | 24.510 |
| Mineral components grinding | 30 | 90 | 5.343 |

### RESULTS AND ANALYSIS

Figure 2 and 3 shows the Composite Curves at non shifted and shifted conditions respectively. In existing process there is a huge gap in efficiency. The minimal temperature approach between both the Hot and Cold side is about 380°C which indicates poor level of heat recovery.

It is depicted from the figure that when cold stream curve is moved straight towards Hot stream so that it touches the hot stream the available temperature difference between hot and cold stream at one end becomes zero. This can be achieved due to the fact that the reference enthalpy for a cold stream can be changed independently from the reference enthalpy for the hot streams. This point is called “Pinch Point”. However, in most of the cases “Pinch Point” is not a point but two points called hot pinch point and cold pinch point and are expressed in terms of temperatures. It is illustrated from the figure that the Hot Pinch is at 1002.5 °C and the cold pinch is at 997.5 °C. At this point the hot utility (HU) and cold utility(CU) demands are minimum and the minimum hot utility is at about 4045.2 KW and the Minimum Cold Utility is at about 29259.25 KW. The heat exchange between the Hot and cold streams turn out to be maximum and is equal to $10^6$ kW.

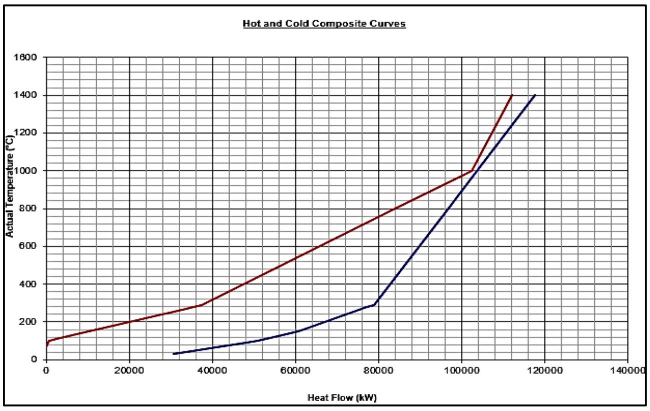


**Figure 2:** Hot and Cold Composite Curves without shifting considering $\Delta T_{min}$ 10˚C

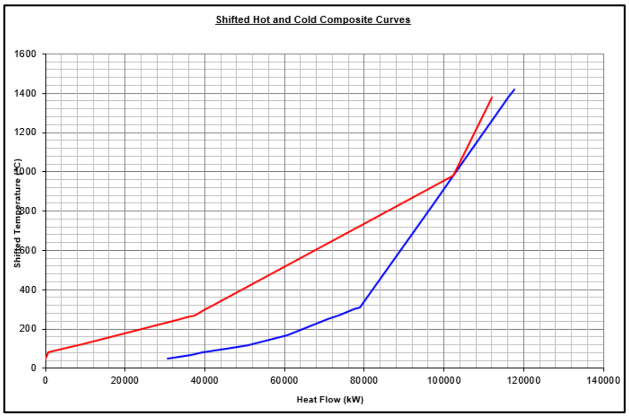


**Figure 3:** Hot and Cold Composite Curves without shifting considering $\Delta T_{min}$ 0˚C

The temperature difference of 0°C is not practically possible because at this condition the net heat transfer is zero and infinte surface is reuired for achieving this heat transfer. For having the feasible solution the temperature difference is kept 10°C (i.e. $\Delta T_{min}$) After keeping the $\Delta T_{min}$ 10°C the Hot pinch is achieved at 992.5°C and the Cold pinch is at 987.5°C and the minimum Hot and Cold utility are at 4738.32 KW and 29951.75 KW respectively achieved which are incrased as compared to having zero temperature difference.

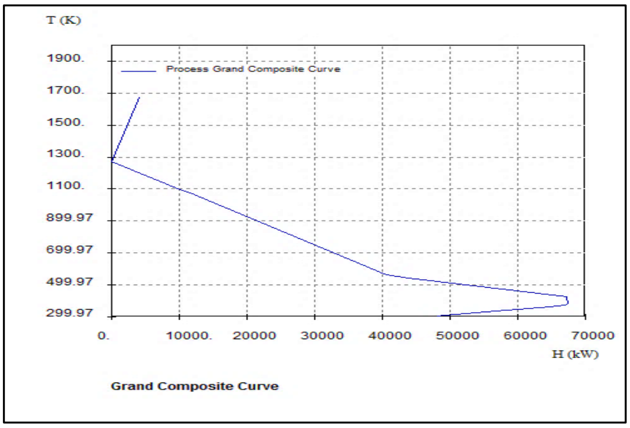


**Figure 4:** Grand Composite Curve

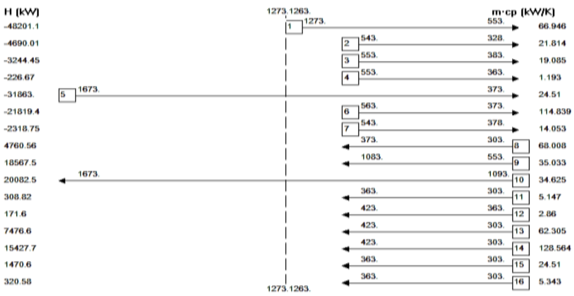


**Figure 5:** Grid Representation of the Process Stream

The changes in net heat flow with respect to shifted temperature is known as the Grand Composite Curve (GCC) or residual heat curve is shown in figure . The GCC shows the variance among the heat available and reuired from the hot streams and the heat required by the process cold streams, relative to the pinch, at a given shifted temperature. [Ian C Kemp]

The GCC also helps to identify if the preheating of cold streams will be supporting to reduces the losses. It is observed that the streams having feeds are all situated beyond the pinch temperature. These streams increases the minimum Hot utilities need thus it can be omitted to retrofit the system in new data set. Similarly the increment in minimum cold utilities need are due to te streams lower then the Pinch point shoul also be retrofit. The maximum energy loss are due to the waste heat supply to the atmosphere.

There is requirement to achieve the most optimum efficiency is to capture the heat that is wasted to the atmosphere and utilize it. The Gases exit to Raw mill, preheater clinker colers containing at this time a lot of heat that shoul be use to increase the efficiency by reducing waste heat. It is called waste heat recovery.

## CONCLUSION

The case study carried out shows that pinch analysis can be useful in a very wide range of cement production process .Pinch analysis of general production process along with waste heat recovery were carried out using the real plant functioning data of a cement plant operating in central India. The major waste heat recovery can be obtained in cold utility side. The outcomes of the study suggests the retrofit of existing cement operations and like productions.

## REFERENCES

[1] Angel Martın, Fidel A. Mato, 2008, "Hint: An educational software for heat exchanger network design with the pinch method", education for chemical engineers 3 (2008) e 6 – e 1 4

[2] Chemical Process Design and Integration, Robin Smith, John Wiley & Sons Ltd.

[3] Ghannadzadeh, M. Sadeqzadeh, Exergy aided pinch analysis to enhance energy integration towards environmental sustainability in a chlorine-caustic soda production process, *Applied Thermal Engineering* (2017)

[4] Ian C Kemp, "Pinch Analysis and Process Integration A User Guide on Process Integration for the Efficient Use of Energy", ISBN 13: 978 0 75068 260 2 ISBN 10: 0 7506 8260 4

[5] Linnhoff March, "Introduction to Pinch Technology" Targeting House, Gadbrook Park, Northwich, Cheshire, CW9 7UZ, England

[6] M.G. Rasul , W. Widianto , B. Mohanty, "Assessment of the thermal performance and energy conservation opportunities of a cement industry in Indonesia", Applied Thermal Engineering 25 (2005) 2950–2965

[7] N. Hallale, Chem. Eng. Prog. 97(7): 30 (2001).

[8] S. Boldyryev, H. Mikulčić, G. Krajačić, N. Duić, "Waste heat utilisation of Croatian cement industry accounting Total Site demands", Proceedings of the 26th European Symposium on Computer Aided Process Engineering – ESCAPE 26 June 12th -15th, 2016, Portorož, Slovenia © 2016 Elsevier B.V.

[9] 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