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Improving Fuel Consumption in Cement Kiln Process based on PLC and HMI

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***Abstract*—Cement is the most important essential component to the building infrastructure development. Taking into consideration that the cement market will record an increasing rate of 15 - 20%, related to the residential buildings development and to the initiation of large infrastructure projects the cement production is of great interest, both from the point of view of product's quality increase and raw material consumption. The main objective of this paper is to show how the process model can be inserted into advanced controllers to allow the successful control and optimization of the process, thereby upgrading the new technologies to the cement kiln, hot air from the Grate cooler is recycled to the Pre-heater, in order to reduce the fuel consumption in burner and high production rate of the cement can be achieved. The cement kiln consists of DRY and WET process. Initially, in pyro-processing the raw mix is fed into cement kiln and heated up to 1500℃ in the presence of limited supply of oxygen, the resultant clinker is now allowed to cooldown up to 100℃. Waste hot air from the Grate cooler is recycled to the Pre-heater, in order to reduce the fuel consumption in burner. Process automation is where the industrial area offers the biggest and most satisfying challenges in terms of combining traditional engineering skills with technological innovation. The cement kiln is enhanced with the new technology using PLC (Programmable Logic Controller) and the output is monitored and controlled with the help of the HMI (Human Machine Interface). The whole system has been implemented and tested using Siemen's PLC.**

***Index Terms*— Cement Kiln, Control System, Clinker Cooling, HMI, Heat recovery unit, PLC, Pyro processing.**

I. Introduction

India is the second largest producer of cement in the world. Cement is an essential component of infrastructure development. India has a lot of potential for development in the infrastructure and construction sector and the cement sector is expected to largely benefit from it. The availability of the raw materials such as limestone and coal aids higher growth in this sector. A cement is a binder, a substance used in construction that sets, hardens and adheres to other, Setting time and "early strength" are important characteristics of cements. The top three producers were China with 1,800, India with 220, and USA with 63.5 million tones for a combined total of over half the world total. In this Process the overall concept of the Cement Rotatory Kiln Process is taken from the various cement manufacturing groups of India Cement manufacture process consists broadly of different stages, Mining, Crushing and Grinding a mixture of Raw Materials to make a fine rawmix, Blending, Pyro Processing (i.e.) "Heating the rawmix to sintering temperature (up to 1500℃) in a cement kiln", Clinker Cooling and Storage, Grinding the resulting clinker to make cement, Packing and Loading. This paper reviews only the Pyro processing and Cooling Technology, where the waste hot air from the Grate cooler is recycled to the Pre-heater, in order to reduce the fuel consumption in burner. The rawmix is fed into the kiln and gradually heated by contact with the hot gases from combustion of the kiln fuel. The raw material is melted to a high temperature makes the raw mix to change its chemical reaction to get the resultant nodules of diameter 1-10mm.This is called clinker. The hot clinker next falls into a Grate cooler which recovers most of its heat, and cools the clinker to around 100℃. The recovered heat is recycled to reduce the Fuel consumption in the burner. The whole Automation Process is designed with the help of Siemens 1200 series PLC "TIA Portal" and the output is monitored with HMI (Human Machine Interface).

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II. Abbreviations

"**PLC**-Programmable Logic Controller"
"**HMI**-Human Machine Interface"
"**NO**-Normally Open"
"**NC**-Normally Closed"
"**PID**-Proportional Integral Derivative"

III. Cement process flow

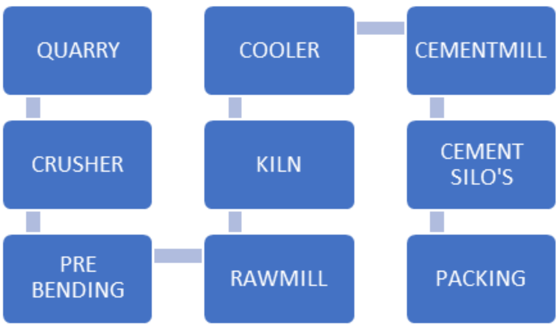

Fig.1: Process Flow Chart of Cement Plant

The Cement manufacture process consists broadly of different stages, Mining, Crushing and Grinding a mixture of Raw Materials to make a fine rawmix, Blending, Pyro Processing (i.e.) "Heating the rawmix to sintering temperature (up to 1500℃) in a cement kiln", Clinker Cooling and Storage, Grinding the resulting clinker to make cement, Packing and Loading. In the above Figure.1 Process Flow chart, this paper considers only the kiln and clinker cooling process. The rawmix is fed into the kiln and gradually heated by contact with the hot gases from combustion of the kiln fuel. The melting causes the material into lumps or nodules, typically of diameter 1-10mm.This is called clinker. The hot clinker next falls into a cooler which recovers most of its heat, and cools the clinker to around 100℃. During the Pyro Processing, Calcination of Lime takes place in the cement rotatory kiln due to high temperature. This Thermal treatment process carried out in the absence of or limited supply of air or oxygen to the rawmix to bring about the Thermal decomposition. The temperature of the kiln is controlled by PLC. The temperature inside the kiln bed is maintained and carbon dioxide is exhausted to control the calcination process. The output is monitored and some control command is given through the HMI.

IV. Proposed Work

This representation refers to a dry and wet process of kiln. The kiln is 180 m long and 6 m in diameter, and mounted inclined to 4º angle about its axis, rotates around 3-5 Revolutions per minute. It is necessary that the mix move slowly enough to allow each reaction to be completed at the appropriate temperature. Inside the kiln the chemical decomposition takes place because of limited supply of oxygen or absence of air. Heat recover from the cooling system is transferred to a precalciner via tertiary airduct to heat the raw mix initially thereby reducing the fuel consumption.

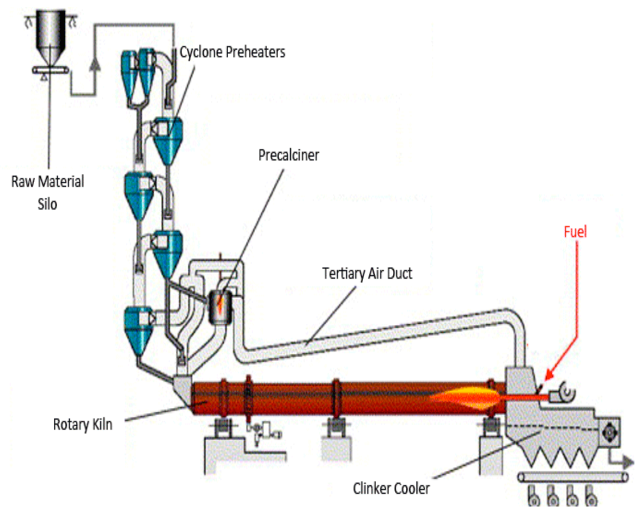

Fig. 2: Block Diagram of Kiln with Tertiary air duct.

V. Calcination Process

Calcination reactions usually take place at or above the thermal decomposition temperature. This temperature is usually defined as the temperature at which the standard Gibbs free energy for a particular calcination reaction is equal to zero. For example, in limestone calcination, a decomposition process, the chemical reaction is

$$CaCO_3 \rightarrow CaO + CO_2(g).$$

VI. Grate Cooling Technology

Grate coolers are widely used in cement industry to recover heat from hot clinkers coming out of rotary kilns. The performance of the rotary kiln is indirectly controlled by heat transfer in the cooler system. The outlet temperature of hot clinkers and a part of melt coming out from the rotary kiln is approximately 1946℃. These hot lumbs should be cooled to a temperature around 673℃, by recovering heat from them, which can be used for any other process. By extracting heat from the clinker the energy consumption is reduced for heating the premix.

VII. Programmable Logic Controller

In 1960's PLC where introduced, MODICON 084 was the world first PLC as commercial product to the US car Manufacturer. The object of automation is safety, reliability, efficiency and less time consumption. PLC as a tool for automation is focused here. The National Electrical Manufacturers Association (NEMA) defines a PLC as "a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic to control through digital or analog input/output modules, various types of machines or processes". In other terms PLC can be define as a "PC designed for an environment". Programming is done with the help of ladder logic language. Siemens 1200 series Controller is used to control the process. Basics concept of relay working plays the main role in the programming(i.e.,) NO (Normally Open) and NC (Normally Closed) Contacts. NO and NC Contacts are consider as the input and Coil is used to indicate the Output.

VIII. Architecture of PLC

A PLC will always consist of input and output interfaces, memory, a power supply and housing functionally. Fig.3.1 shows the architecture of a PLC. A PLC examines the status of input interfaces and in response and controls something through output interfaces. Combinations of input and output data are referred to as logic. Several logic combinations are usually needed to carry out a program or control plan .The control plan is stored in memory using a programming device.

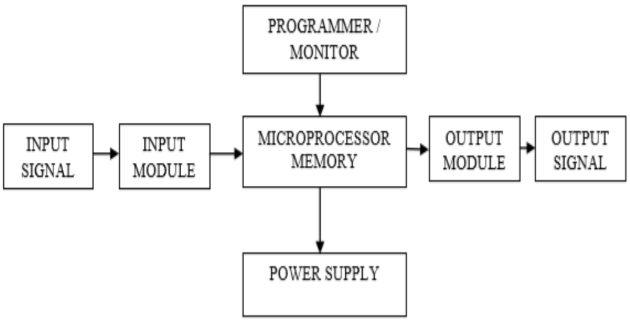

Fig .3: PLC Architecture

IX. PID CONTROLLER

A proportional–integral–derivative controller (PID controller or three term controller) is a control loop feedback mechanism widely used in industrial control systems to get the desired controlled output. A PID controller continuously calculates an error value as the difference between a desired set point and a measured process variable and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively).

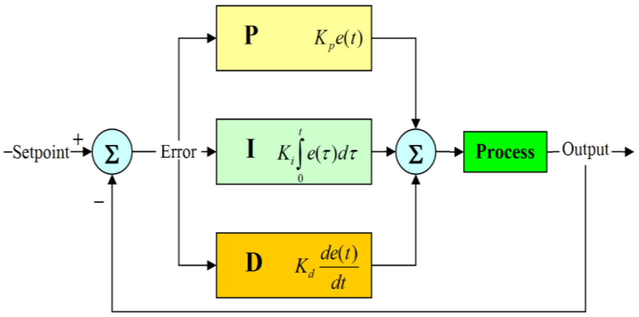

Fig .4: PID Controller Action

X. RESULTS AND DISCUSSION

Below Figure 4. Shows the HMI window of the Cement Rotatory Kiln process.

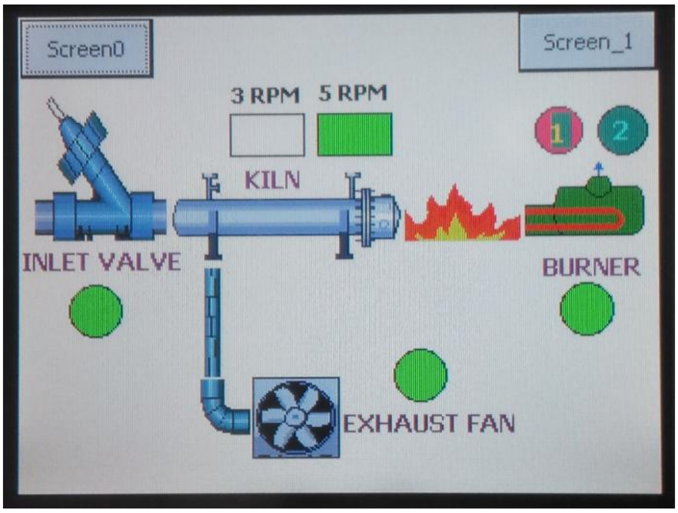

Fig.5: Front Pannel HMI Screen.

In the HMI window we can see the current status of the Process. We can see the status of the burner, motor, exhaust fan and the inlet valve of the KILN. Initially the kiln gets started after some delay the Inlet valve and Burner turns on based on the temperature of the clinker the fuel level is controlled. Exhaust fan gets started when the Co2 level gradually increases inside the kiln. The below table 5.1 shows the status of the process.

UNIT	STATUS OF THE UNIT
KILN	ON
BURNER	ON
EXHAUST FAN	ON
INLET VALVE	ON
MOTOR	3 Rpm (OFF) 5 Rpm (ON)
FUEL	(1) HIGH FUEL (ON) (2) LOW FUEL (OFF)

Table .1: Status of the Process

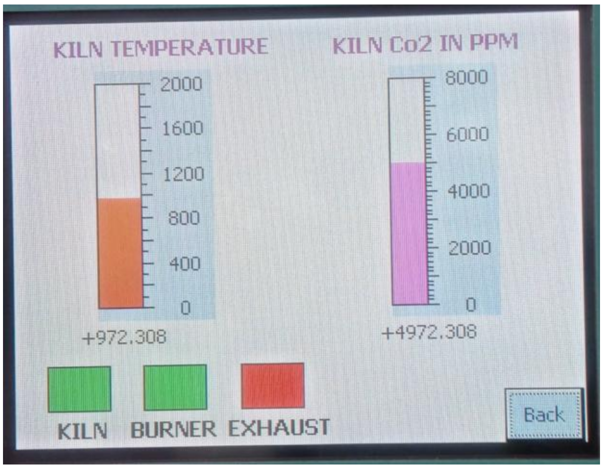

Fig .6: Temperature and Co_2 Monitoring

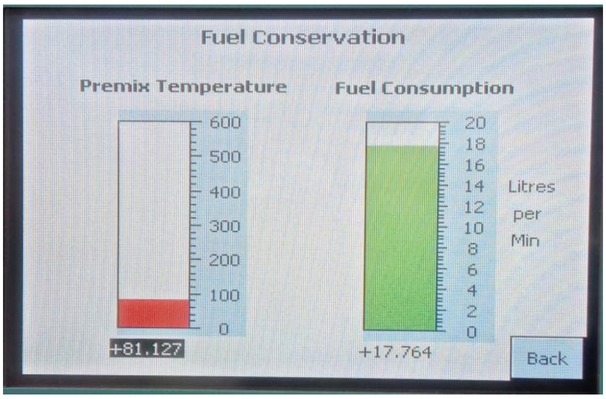

Fig.7: Fuel Consumption at Minimum Temperature.

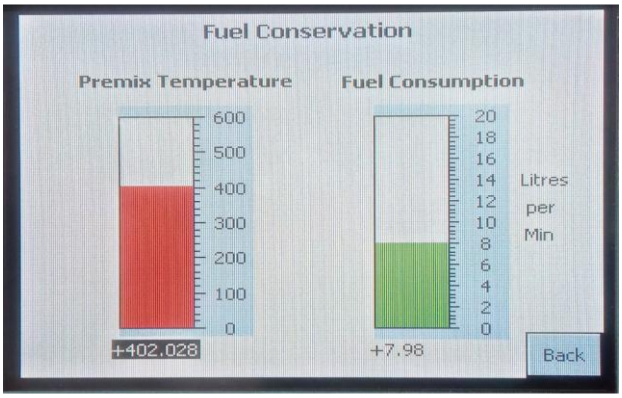

Fig.8: Fuel Consumption at Maximum Temperature.

RECYCLED TEMPERATURE (°C)	FUEL CONSUMPTION (ml)
+81.127	17.764
+201.014	11.285
+402.028	7.98

Table .2: Comparison table for fuel consumption based on recovered heat.

XI. CONCLUSION

The proposed work conclude that cement kiln is heated up to 1500°C in the presence of limited supply of oxygen, the resultant clinker is now allowed to cooldown up to 100°C. Waste hot air from the Grate cooler is recycled to the Pre-heater and reduce the fuel consumption in burner. Measured signal is fed into the Programmable Logic Controller and the action takes place to get the desired output. Thus the Graphical representations of the results for Fuel Consumption is reduced in the burner by the recovered heat and the whole process is monitored with Human Machine Interface.

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