Preventive Maintenance of Kiln Furnace used for Production of Ceramic Insulators using Thermography

M. Mahesh, M. Swamy, K. Appa Rao, V. J. Thomas, G. Swaminathan* and M. S. Rawat
Corporate R & D, BHEL, CTI Bangalore, BHEL
E-mail: mahesh@bhelrnd.co.in

ABSTRACT
Manufacturing of ceramic Insulators involves crushing of raw material, compaction to desired shape and size in green stage followed by firing in the kiln furnace. In this furnace the product undergoes drying, baking, sintering and cooling. In case of malfunctioning of the furnace the final product becomes defective resulting in material and energy loss.

Infrared thermography is a proven non destructive technique having application in various areas [1]. This paper describes using an infrared camera for examination and monitoring of refractory-lined process kiln used for production of ceramic insulators. Refractory is a temperature-resistant lining that is used for lining the kiln which operates at very high temperatures. The refractory lining protects the shell of the kiln from the hot gas circulating inside the kiln. Failure of refractory linings can have very serious consequences.

Conventionally refractory repairs and replacements are being undertaken based on visual internal inspection during shut down. The present study not only enabled us to identify areas of refractory lining requiring repairs and replacement but also revealed problems in cooling system inside the lining which normally is not visible otherwise. Such predictive maintenance enables the operator to plan the work scope for a planned shutdown well in advance. One of the main advantages of this technique is that the examination is done on-line.

Keywords: refractory, thermography, cooling effect, process, kiln, ceramic insulator

Introduction

Industrial furnaces working at higher temperatures use fuel inside the furnace. Refractory lining/insulation lining is required to retain the heat inside the furnace thus improving energy efficiency and reducing fuel energy costs. Kiln furnace, used for the production of ceramic insulator, has long tunnel shaped structure as shown in Fig. 1. This long furnace is subdivided in to four zones. First zone is called drying zone where the temperature is maintained at around 150°C to remove moisture from the green ceramic insulator. Second zone is called baking zone with temperature around 800°C where the oxides of insulators start to recrystallise and hence expansion and contraction takes place in the ceramic insulators. Third zone is called sintering zone with temperature around 1100°C where the oxides fuse to become complete ceramic product. Fourth zone is called cooling zone where cooling is done to avoid sudden thermal shocks. The refractory lining of the kiln is to insulate the temperature from the surroundings and save energy losses. The temperature on the outer surface of the kiln should be around 80°C. Passive thermography is utilized for condition monitoring of the kiln furnace in operation from outside.

Refractory lining failures

A Batch type furnace is used for the production of ceramic Insulators. The furnace is divided into three zones a) Drying Zone b) Firing Zone and c) Sintering Zone. A gradual heating is required to avoid preferential leakage of steam through vents thereby weakening the product leading to fracture.

Drying Zone: In the drying zone temperature is maintained around 200°C. The moisture and any volatile matter present over green ceramic surface goes off.

Firing Zone: In this zone the temperature is maintained up to 800°C. The moisture present deep inside the insulator dries up and quasi crystals of different oxides start forming.

Sintering stage: In this zone the temperature is maintained up to 1200°C. All oxides are sintered and form a solid body of Insulator.

The corrosive gases flow at high velocity inside the kiln. The refractory lining of kiln is provided to bear the erosion and thermal insulation. The fluid dynamics of gas inside the kiln is maintained by kilns refractory lining. Wearing of the lining not only affects the product quality but also leads to loss of energy. Advancement has been made to improve the property of the refractoriness by mixing various grades of different oxides by the operational experience and technological developments. However refractory lining failure remains one of the most common reasons for unforced shutdown of the kilns. The reliability of the kiln lining is one of the main criteria for efficient production/quality of the product.

To improve the efficiency of the kiln lining various arrangements have been made in Ceramic production kiln incorporating thermocouples at different zones to record the temperature. Various cooling methods have also been adopted to properly maintain inside temperature of the kiln.
Thermography principle and camera setup

The principle of thermography is to pick up the infrared signals falling in the range of 1-4 Micrometers or 7-11 Micrometers through germanium lens to Uncooled Bolometer. The excitation energy received then processed with in the camera to get converted into image. The images will have all the information of different temperatures of the scanned body. Before scanning the body the camera needs to calibrate like (emissivity, atmospheric attenuation etc.) for particular application. A complete scan of the entire length of kiln was carried out by a non-contact thermography. Due to the large number of measurement locations and difference in surface temperature of the kiln at different temperature zones, it is impractical to measure the emissivity and the reflected ambient temperature at different locations. Emissivity at each location was therefore set to ONE. A Thermography Camera with standard features was used to examine the kiln furnace. The camera works in far infrared spectrum i.e. 9-11 micrometer and the camera has been provided with temperature ranges -20°C to -80°C, 10-150°C and 500-1500°C. The camera is provided with germanium lens with 20° instantaneous field of view. Telescopic lens was also used to see the kiln from far off distance where accessibility was poor. The images were captured in storage device called PCMCIA Personal computer memory card international association. The images were then analyzed using reporter software. When the camera is initialized its level and span is adjusted. Thermal tuning or focusing is carried out to reduce blurring of the image. Once the image is thermally tuned camera can be used for experimentation.

Inspection results

Figure 1 shows the general outline of the kiln. The kiln comprises of narrow portions at the beginning and end portions with firing chamber in the middle. The kiln is lined with fireclay bricks with different alumina composition.

Location 1

The outside surface of the kiln was examined by thermography as shown schematically in Fig.1. The thermal images were recorded and the images are processed by a computer. From the temperature profile of Fig.2 and Fig.3 it can be clearly seen that a maximum temperatures of 170°C was observed near the firing zone. Normally a temperature of 80°C is maintained on the outside of the kiln. The measurement of high temperature on the outer surface during operation of the kiln clearly indicates the erosion of refractory internals by corrosive gases at these locations. Due to such erosion of refractory internals, the non-uniform heat flow conditions can lead to crack formation in insulator.

Location 2

Figure 4 shows the hood portion of the kiln that gives a clear indication of excessive wear of the kiln. Doors are used in the kiln furnace to remove the fallen insulator inside the kiln during the production process. The doors are supposed to be thermally well insulated to avoid leaking of gases to the outside atmosphere. In the present case thermography images were recorded at the door position and the thermal operation of the kiln.
A temperature of 170° i.e. white region at the upper portion which may be due to improper sealing/closing of the door.

**Location 3**

To improve the life of refractory lining and to maintain inside temperature of the kiln it is cooled with the passage of air/air-water through cooling nozzles. The nozzles are well distributed inside the kiln refractory lining and are not visible to naked eye during opening. As shown in Fig. 6&7, out of the four nozzles, gas coming out of the nozzle can be seen through one nozzle. This shows that there is blockage of the nozzle at the exit side and cooling gas is not able to pass to the kiln. Such malfunctioning can be seen only with thermography during operation.

**Location 4**

The refractory are joined together by using insulated binder. Over and above there will be high refractory fine powders mixed with binder pasted over the refractories from
inside of the kiln. On continuous run the refractory lining deteriorate by corrosive gases inside the kiln. Fig.8 and 9 above shows preferential channel wearing at the boundaries of the refractory lining.

The build-up of solids at the bottom was due to a change in process conditions in the furnace firebox that produced solid ash which accumulated in the bottom of the ducting elbow and can be seen as shown in Fig.10.

Summary

The insulation lining of the kiln is heavily damaged in portions like hood, firing zone and sintering zone. The kiln is maintained in the positive pressure to keep it away from entry of atmospheric gases. However the leaking of the gases through doors which cannot be seen otherwise by any means has to be avoided. After thorough examination of the kiln it was recommended to stop the kiln and change the furnace lining as soon as possible to avoid energy losses. Present investigation has shown that thermography helps in understanding the condition of kiln during operation. This study has not only helped in identifying faults with refractory lining but also helped in improving maintenance of cooling nozzle and sealing arrangement.

References

1. Update on Infrared Applications for Steam Turbine Condenser Systems Mark A. Lanius’ PECO Energy Company, Peach Bottom Atomic Power Station MS A2-IN, 1848 Lay Rd., Delta, PA 17314 USA