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Energy Efficient Tunnel Kilns with Superlative Firing Atmosphere for Ceramic Industries

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Abstract
Khurja is a pottery cluster having around 500 manufacturing units in the state of Uttar Pradesh (India). These units manufacture whitewares i.e. table ware ceramics (Bone china & Stoneware), artistic items, chemical porcelain, tiles, sanitary ware and porcelain insulators etc. In Khurja, about 110 units are firing their product in oil fired tunnel kilns. Due to low fuel efficient kilns, large quantity of fuel is used for firing of white ware ceramics. A study was carried out on the firing atmosphere in oil fired tunnel kilns being used for the firing of ceramics. These kilns do not have much engineering design inputs. Large fuel consumption is the biggest challenge due to poor designs. The aim was to reduce fuel consumption by various technological interventions like increasing firing zone length and chimney height and diameter, redefining the ratio of CO, O_2 and excess air etc results in the reduction in firing cycle hours, improvements in products loading density, improvement in product quality and reduced emission of Green House Gases(GHG). A number of kilns were chosen for the study. The appropriate ranges of CO, O_2 and excess air in the flue gas were optimized for oil fired Kilns which resulted in increased kiln efficiency. Proper kiln insulation resulted decrease in the skin temperature. The control of excess air resulted in better product quality.

Keywords: *Ceramic Industry, Tunnel Kiln, Flue gas, Green House Gases.*

I. INTRODUCTION

Energy efficiency being a low cost solution also results in the reduction of Green House Gases (GHG) emission and meets the clean environment objectives. The paradigm would have to focus on a lower energy intensive path of development, also aiming at the reduced carbon emissions and improved efficiency in production and consumption. In India, there is a huge gap between energy demand and supply. Though efforts are being made for additional power generation capacities, there is a need to utilize available energy sources optimally [1]. The conservation of energy is also an essential step that can be taken towards overcoming the mounting problems of the worldwide energy crisis and environmental degradation [2]. Developing countries have undertaken measures for enhancing energy efficiency and build capacities to reduce energy usage.

Khurja supplies a large portion of the ceramics used in the country, hence it is sometimes called *The Pottery Town*. The history of Khurja pottery goes back to about 600 years ago when some of potter's families moved from Delhi to Khurja during the reign of Mohammed Bin Tuglak. Starting with red pottery they moved to introduce blue glaze on red clay articles. However, the ceramic industry has been a boon and bane for the town, providing it with much needed employment and chimneys giving out pollutants. There are nearly 500 small scale sector units, making ceramic items like table wares ceramics (Stoneware, Earthenware, Bone China ware), artistic products, chemical porcelain, tiles, sanitary ware, ceramics for industrial applications and porcelain insulators etc [3].

A great contributory factor towards the setting up of the concentration of small scale ceramic industries in Khurja is the positive attitude of the government of Uttar Pradesh. Since 1942 the U.P Govt. decided to set up ceramic industries at Khurja. At that time the industry was equipped with three small kilns , two chimneys and three ball mills. In 1949, U.P. govt. made thoughtful consideration of the utilization of the machinery and other capitals goods and converted it into a Govt. Pottery Development Centre, which has promoted the development of the industry. In terms of economic growth rate, India is emerging as another economic giant, which is just next to China. To reduce the consumption of fuel in ceramic industries, PCRA sponsored different projects to CSIR-CGCRI, Khurja Centre which resulted huge amount of energy saving in the form of fuel or say reduction in emission of GHG [4].

The ceramic industry in India predominantly uses petroleum products as the source of energy. Energy cost in ceramic industry is as high as 40 percent of total production costs. The temperature and uniformity of firing in modern tunnel kilns largely depends on the used setting arrangements [5]. A mathematical model was studied, representing the phenomena of heat transfer [6]. A thermodynamic analysis of tunnel kilns can yield valuable information about the energy conversion processes in the kiln (combustion, energy dissipation) [7]. In roller hearth kilns where products like table ware and tiles move over

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the ceramics roller tube for the firing process, which is a fast firing process there by reducing the fuel cost[8]. Most of the energy got wasted due to leakage from the surface. In advanced countries car lining is done by gunning. This is the system comprising use of bulk ceramic fibre, an organic fibre and an organic foaming binder through feed hose and nozzle [9]. In good insulated furnaces, the body shell temperature is restricted to 35-40^{o}C above atmosphere [10]. For efficient combustion process, flue gas is required to be analysed. In most of the kilns the oxygen level in the chimney duct is in the range of 18-20% - 15% near the charging door and 5% in the firing zone. It shows that there is no draught at the chimney bottom and most of the flue gas comes out through the gaps at the edges of the charging door [11]. Excess air supply for combustion of fuel always increases fuel combustion. To enhance cooling rate additional cool air is supplied and also to remove part of this air before entering into the firing zone, multiple hot air removal port system has been incorporated in the cooling zone [12]. Thus, a substantial amount of energy could be saved by preventing leakages in kilns, through improved controls of the combustion process, recovering and recycling heat generated by firing, as well as through improved designs of kilns and other equipment/machinery.

A study was carried out on the firing atmosphere in oil and gas fired shuttle & tunnel kilns being used for the firing process in the ceramic industries at Khurja. The effects of all the technological interventions in ceramic whiteware firing process have been discussed in this paper.

II. EXPERIMENTAL

To conserve energy in the Ceramic industries at Khurja, several activities were undertaken. After surveying, it was found that these were consuming lot of fuel for firing the products. It was observed that kilns used were not either well equipped or designed properly so as to give the maximum output. Some measures have already been adopted for improvement of tunnel kiln thereby reducing the specific oil consumption by 15-20% [13]. There is lot of scope to reduce the fuel consumption by improvement in the following area in tunnel kiln like improvement in tunnel kiln design, improvement in insulation materials to prevent heat loss, improvement in drafting system of flue gasses, utilization of waste heat from cooling zone and implement of fuel efficient burners.

The tunnel kiln design was improved by increasing the kiln length, improvement in chimney design for better drafting of flue gasses, installation of pipes for waste heat recovery from cooling zone, improvement in insulation materials of kiln to reduce heat loss through surfaces and improvement in the combustion system with the use of improved burners.

The higher fuel consumption was also due to improper combustion of the fuel. Since, the firing was operated manually and there was no significance of flue gases generated during firing. To know the combustion efficiency, analysis of flue gas was carried out utilizing a Portable Flue Gas Analyser, Kane International, U.K. [14]. It can determine the Excess Air, O_2 and CO levels.

For optimum combustion, the real amount of combustion air must be greater than that required theoretically. This additional amount of air is called “excess air”. A certain amount of excess air is needed for complete combustion of furnace oils. Excess air adjustment has a direct relationship with smoke. If chimney emits a hazy brown smoke, the combustion is considered proper. But if the chimney emits black smoke, it indicates incomplete combustion and available fuel wastage. Similarly a chimney that is clear & smokeless indicates too high excess air and wasted fuel. So, the flue gas data was analysed and optimized to reduce the Excess air in the kiln. Data were collected before and after its implementation.

The heat radiated by the fired products and the kiln car mass, was wasted after the cars come out from the cooling zone. So, an arrangement was made to use this heat in pre heating zone of the kiln as well as for drying of green wares. Data were recorded before and after making changes.

III. RESULTS AND DISCUSSIONS

The modifications were made in the design parameters of tunnel kiln as furnished in Table-1. The firing zone length, chimney height and chimney diameter of the Tunnel Kiln has been increased. The burner number has also been increased from 4 to 6. More number of trolleys inside the kiln resulting in increased production.

TABLE-1: General Data of Tunnel Kilns

S. No.	Particulars	Before Intervention	After Intervention
1	Length of Preheating Zone (ft)	37-56	37-56
2	Length of Firing Zone (ft)	14-16	16-20
3	Length of Cooling Zone (ft)	32-68	32-68
4	Total Length of Tunnel Kiln (ft)	95-116	105-144
5	Chimney Ht.(ft) and Diameter (inch)	10/8.5 – 20/8.5	20/16
6	Burner (Nos.)	4	6
7	Number of trolleys inside kiln	17-36	18-36

Since energy is radiated by the surface or skin of the kiln during the firing process. In order to prevent heat loss from the surface, the insulation of the kiln has been improved by using HTZ ceramic fibre. After its implementation, it was observed that the average skin temperature of Preheating Zone, Heating Zone and Cooling Zone have been significantly decreased (Table-2). Also the chimney pipe temperature has been decreased slightly.

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The excess air and CO were maintained at 65% and 6ppm respectively, there was a reduction in warpage of wares with improvement in the whiteness [15].The best suitable ranges of CO, O_2 and excess air in the flue gas were optimized for oil fired Kilns which resulted in increase in the kiln efficiency by 3-4%. The control of excess air also resulted in reduced warpage and improvement in the product quality. The flue gas analysis is given in Table-3.

TABLE-2: Skin Temperature Data of Tunnel Kilns

S. No.	Particulars	Before Implementation (^oC)	After Implementation (^oC)
1	Skin Temp. of Preheating Zone	59-107	50-60
2	Skin Temp. of Firing Zone	83-161	76-108
3	Skin Temp. of Cooling Zone	57-78	52-60
4	Chimney Pipe Temp. above 3' from roof of kiln	58-68	50-70

TABLE-3: Flue Gas Analysis of Tunnel Kilns

Factor	Before Implementation	After Implementation
O_2 %	16.6-19.0	16-18
CO ppm	14-137	13-125
Excess Air %	375-995	344-630
Efficiency %	78.3- 86.6	82.6-89.8
CO_2 %	1.5-3.3	1.6-3.5
Flue Temp.^oC	40-160	45-122
Ambient Temp.^oC	34.6-41.8	35.2-42.8

After considering all these design modification, it was found that production per day has been significantly increased with the improved product quality. The pushing time has been decreased by 5-10 mins. Also the fuel consumption has been decreased appreciably (See Table-4). Thus we get total fuel saving of around 14-26 %. And the productivity has been increased by 8-14 %.

TABLE-4: Production and Fuel Saving Data of Different Kilns

S. No.	Particulars	Before Implementation	After Implementation
1	Production/day (MT)	2.8-8.5	3.03-9.68
2	Pushing Time (Mins.)	60-80	55-70
3	Fuel Consumption/ MT (lit.)	129.4-239.3	96-204.6
4	Total Fuel Saving (%)	-	14.39-25.81
5	Productivity Increased (%)	-	8.04-13.88

IV. CONCLUSIONS

Proper insulation of inside surface of the kiln by using HTZ ceramic fibre resulted decrease in the skin temperature. Some of the Kilns resulted oil saving of 14 - 26 % with increase in productivity by 8-14% on modification. The control of excess air also resulted reduction in rejection due to warpage by 80 - 90 % and improvement in product whiteness by 20 % minimum. The reduction in the energy consumption achieved with the use of control equipments and insulation. In this study, we got energy saving on modification in kiln design is 14.4 - 25.8%. Energy Saving through controlled Excess air we get Fuel Saving of 1.41-8.22%. Most suitable & least cost technology was identified for improving energy efficiency and GHG emission reduction in tunnel kiln at Khurja.

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