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Study of high emissivity coating of ceramic material for energy conservation

Dipen V.Chauhan[1], S. N. Misra[2] and R. N. Shukla[3]

[1]Department of Chemical Engineering, L. D. College of Engineering, Gujarat Technological University, Ahmadabad, India
[2]Dr. S. N. Misra, Scientist-in-Charge, Central Glass and Ceramic Research Institute, Naroda Centre, Ahmadabad, India
[3]Department of Chemical Engineering, L. D. College of Engineering, Gujarat Technological University, India

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ABSTRACT

Present paper reports a study on the development of high emissivity coating materials with certain properties which essentially increase the efficiency of heater system. In this study, a high emissivity .Coatings is applied on refractory substrate. The Coating materials are capable of absorbing and reradiating thermal energy. The emissivity coating material is applied at the outer surface of the ceramic heater where the heating elements are inserted in the groove. The objective is to direct the radiation heat evolved during electrical heating glowed upwards so as to increase faster heating rates. Here, an attempt is made to study the effect of suitable coating with higher emissivity on the refractory substrate in the laboratory. The objective is to find out effectiveness of the emissivity coatings on the consumption of electricity units in heater applications. The coatings materials are consisting of various combinations of Zirconium, Silicon Carbide, Chromium, suitable binder, additives and some amount of clay. The binder is formulated to adjust desired consistency and drying characteristics of paint. The coating material is applied as usual methods such as spraying whereby a uniform thin layer is achieved. To increase the solid content, the coating is applied no. of times to study dependency of thickness. Some coating was also made on the ceramic heater by brushing etc. A fixed quantity of water has been subjected to boiling and time is noted when the first boiling starts. This study has demonstrated the heating time for the coated and uncoated heater. The resultant time of heating has been reduced and the unit obtained through based on calculation showed a reduction in energy. Thus, suitable coatings developed in the laboratory showed a result oriented practical findings which could be useful in various heater/furnace applications whereby such coating reradiate the heat absorbed on the surface and thus saves energy. Also, it is shown that with the thickness the emissivity coating, increases with the increase in temperature in this experiment carried out in the laboratory, an average of energy saving up to 11-15% has been observed on the coated electric heater system.

Key words: emissivity Coatings, Reradiation, Binder, Heat Transfer, Ceramic, emissivity.

INTRODUCTION

Ceramic industry in India especially in Morbi cluster is growing at a higher rate due to its strategic advantages w.r.t raw materials availability, vast resources in one place and natural gas as a cheaper and convenient fuel source. The ceramic industries are dominated in Gujarat state and covered more or less nearly 70 -75% of total ceramic production in India as a whole. The productivity of these types of products consisting of ceramic tiles, sanitary wares, crockeries and refractories etc require quite a good amount of fuel energy for firing the raw goods. Due to energy intensive process, the cost of fuel counts almost 35-40% of the total production cost and hence any savings would have been huge gain for these units. Hence, every effort is needed to find alternate fuel source, reduction in energy consumption and other remedies to see the total cost of production could get reduced.

In this direction, the concept of taking a ceramic coating materials for finding suitable energy conservation by way of reradiating the heat absorbed in the hot face of the furnace lining could be found beneficial in reducing the heat loss and save further fuel energy .With this objective, a research work is taken up to develop a ceramic coating and study on ceramic heater has been attempted in the laboratory to find out it's advantages**.**

In the state of Gujarat, a large no. of energy consuming industries are located in Morbi, Thangadh ,Ahmedabad and in the Himatnagar cluster besides in Khurja, Jaipur and in Kerala. [1,2] The firing of the ceramic based materials especially ceramic tiles are taking place in the roller hearth kiln and sanitary wares and crockeries are fired in the tunnel kiln. Nowadays, the high temperature kilns are lined with mostly low mass ceramic fibre for better insulation and higher energy conservation. .In some other furnaces, mostly in the tunnel kiln, the lining is a combination of ceramic fibre as well as high temperature insulation bricks. In this work, it is felt that by suitable coating with high emissivity properties on the furnace lining could save fuel cost by directing the maximum amount thermal energy towards loading area and thus effectively reduce the time taken for heating the load. In general, the efficiency of coating could be more effective when the furnace is heated at a temperature around 1000˚C or above. Furnace or kiln is major energy intensive equipment in ceramic industry. The electric energy is used to heat the furnace with its various accessories such as blowers, fans, compressors, exhaust etc. to attain the desire temperature. Then chemical energy is used for combustion of various fuels such as natural gas, LDO, producer gas, petcock, coal etc. in the ceramic industry. The higher energy requires for firing in the furnace or in the kiln .Around 60-65% of the energy consumes for heating the furnace or kiln [1,2,3].

It is observed that there is sharp increases in production activity in the region as large no of ceramic industries have expanded their business activity. This has resulted in significant increase in the energy consumption and usage of various fuels. In turn, the environment is becoming polluted and lots of gaseous particles are floating around in the air causing severe environmental impacts. It is the challenge too the scientific communities to find out suitable alternatives and at least find solution to reduce energy consumption by some means. In this aspect, high emissivity type coating could reduce the total energy consumption by way of reducing various forms of heat losses.

High emissivity Coating

High emissivity coating or ceramic coatings have been used in the electric Arc Furnace during steel making and other industries for many years [4]. One particular use of high emissivity ceramic coating is in the field of furnace lining refractories. High emissivity coatings are applied to the interior part of the furnace chamber to improve efficiency of the furnace. This type of coating generally comprise of high emissivity agent with various additives and binder / suspension agents [4].

In gas or oil fired furnace, the gases are fired and after combustion in presence of air got they absorbed and emit radiation at specific wave length corresponding to the spectra of CO_2 and H_2O. Radiant energy from hot gas reflected back from the furnace wall does not change its wavelength and hence can be significantly absorbed by gas before reaching to the load surface. Radiation that is absorbed by the wall on account of its emissivity is reemitted. If the wall is black or a high emissive then more radiation will reach the load surface without reabsorption by the gas. Thus net redistribution of energy occurs across the spectrum resulting in an increase in heat transfer to the load. Figure 1 shows the schematic presentation of the radiation occurring in furnace. [5,6,7]

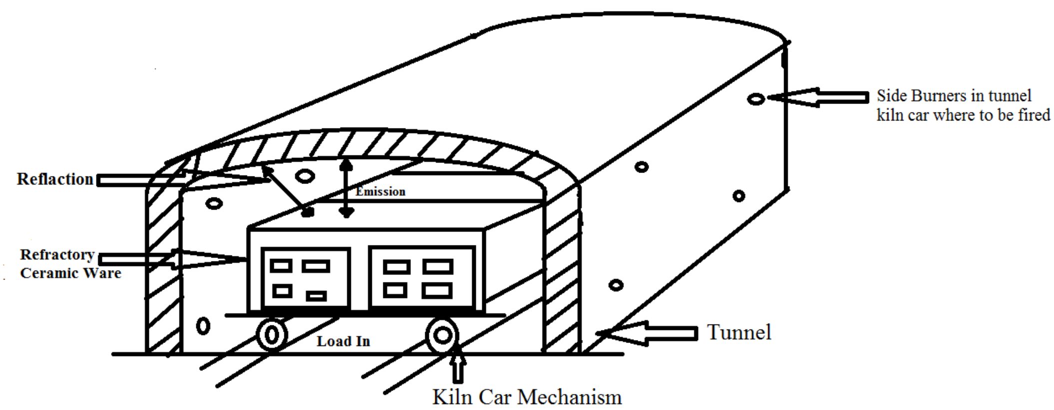

Fig.1 The radiation interchanges between a non-grey gas and refractory and load surfaces in a furnace.

The high emissivity coating is applied on refractory or metal substrate to expose at high temperature. It should be remembered that high emissivity coating are not insulator or reflector. They are not barrier to conductivity of thermal energy through a furnace wall. Insulating refractories are generally place behind dense refractories at the cold phase of refractory design [7]. Figure 2 explain the detail in the picture.

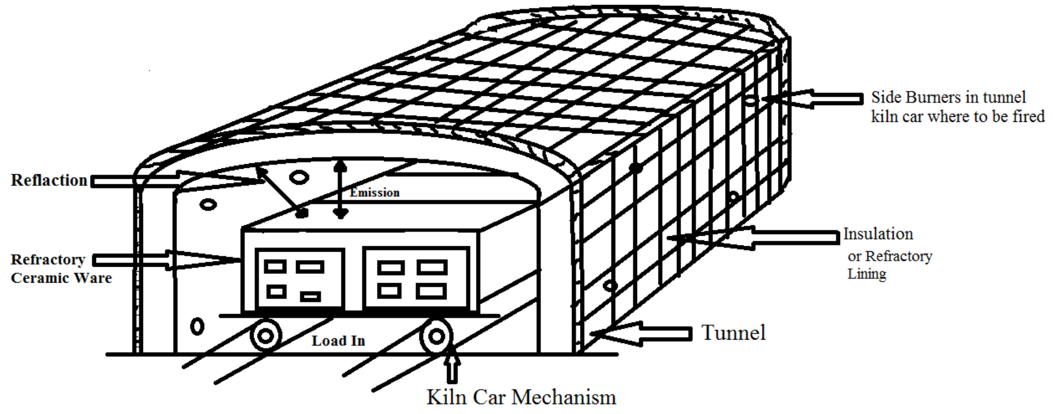

Fig. 2: Reheat furnace with Insulating Material

When high emissivity coating is applied to hot phase of furnace, then radiant energy from the burners and convective energy from kiln atmosphere is absorbed at the face of surface of the coating and re radiated to cooler furnace load, where the temperature at wall furnace is higher than furnace load. [7] Figure 3 explain the detail in the picture.

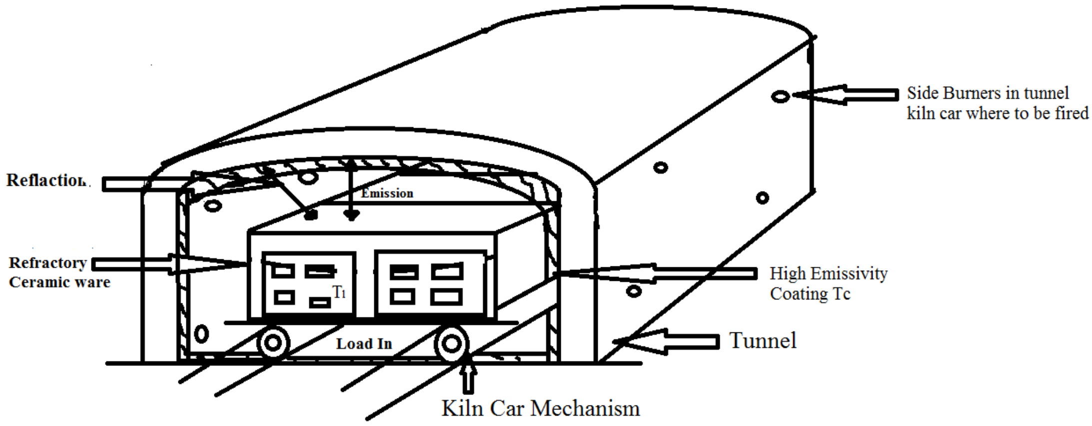

Fig. 3: Reheat furnace with high emissivity coating applied to the refractory hot face.

Emissivity

Emissivity is often considered as inherent physical property that does not normally change. A surface with high emissivity has the ability to absorb radiant and convective energy at high temperature and re radiate up to 95% of that energy. In turn these get absorbed by the surface of gas which is cooler than coating. When hot face emissivity of a substrate is increased by applying coating, radiant energy from burner or electric arcs and convective heat from contract with furnace gases are absorbed and re radiated.[8] In general, the emissivity of furnace that operate at high temperature is found to be 0.3. But with the help of emissivity coating, this can go to up to 0.85-0.95.This significantly results in increase of heat transfer through radiation. [8]

The amount of high emissivity coating is predicted in the following equation:

$$Q = E_w * \sigma * (TC^4 – TL^4) \qquad \text{------------} \quad (1)$$

Where:
Q = reradiated energy.
E_w = emissivity of the coating.
σ = Stefan-Boltzmann constant.
TC = coating temperature.
TL = load temperature.

In the case of E_w being 0.85-0.95, this refers to the reradiation of up to 85 to 95% of the energy absorbed, in the presence of suitable cold load. Emissivity is a property of the coating, which is in this case, remains between 0.85 and 0.95 up to temperatures in excess of 3000°F. At steelmaking temperatures, most refractories and metals have emissivity (E_w) around 0.2-0.3. Since delta T is raised to the fourth power, the amount of re-radiated energy increases exponentially as the temperature difference between the coating and the load increases. If TC^4-TL^4 is small or zero, then a high emissivity coating will be of no value or will not be cost effective. [8, 9]

MATERIALS AND METHODS

1. High Emissivity Coating Preparation

Emissivity coating is prepared by two major components: A high emissivity agent and a Binder. A mix of various constituents (as shown in Table.1) is weighed in a weighing scale and added water to maintain a coating consistency after milling for certain duration. Ceramic coating thus prepared with desired rheological characteristics have been applied onto the surface of ceramic substrates by spraying /brushing. The settling of the slip is made to a minimum level with a higher solid content. The slip is coated on suitable ceramic substrate such as refractory insulation bricks, ceramic insulation fibre for attaining desired thickness. The details of the formulation of the coating materials described in Table.1.In each case the fast grinding mill is used with a quantity of the material is kept 250gms.

Table1: Formulation of Coating Materials

Composition	A	B	C
Zircon silicate (Wt %)	90-95	85-90	80-85
Other Additives	2-5	2-5	2-5
Dispersion agent (Wt %)	0.3-1	0.3-1	0.3-1
Binder (Wt %)	0.3-2	0.3-2	0.3-2
Phosphoric acid(ml)	2-5	2-5	2-5
China Clay (Wt %)	2-5	7-10	12-15

60-65% of water is added during wet grinding. All the ceramic substrates have been spray and brush coated .The sprayed coated material looked to be more uniform as compared to that of brushing.

2. Experimental Set Up for energy calculation of the emissivity coated wares.

In this experiment, the coated heater substrate (in the side of the grooves of electric heater's plate) Attached with heating elements winded on the groove portion and connected with electric supply line. The detail of the experimental setup is shows in figure 5, contain mainly 1500 watt rated electric stove, beaker, thermometer etc. Electric heater contains electric plate and coil for supplying electric energy as source (See figure 6 and 7). Coating is applied inside grooves of the electric plate so that they reflect more heat energy towards load placed on the equipment. In this case, the cold load is a fixed quantity of water kept on the beaker for heating to just boiling.

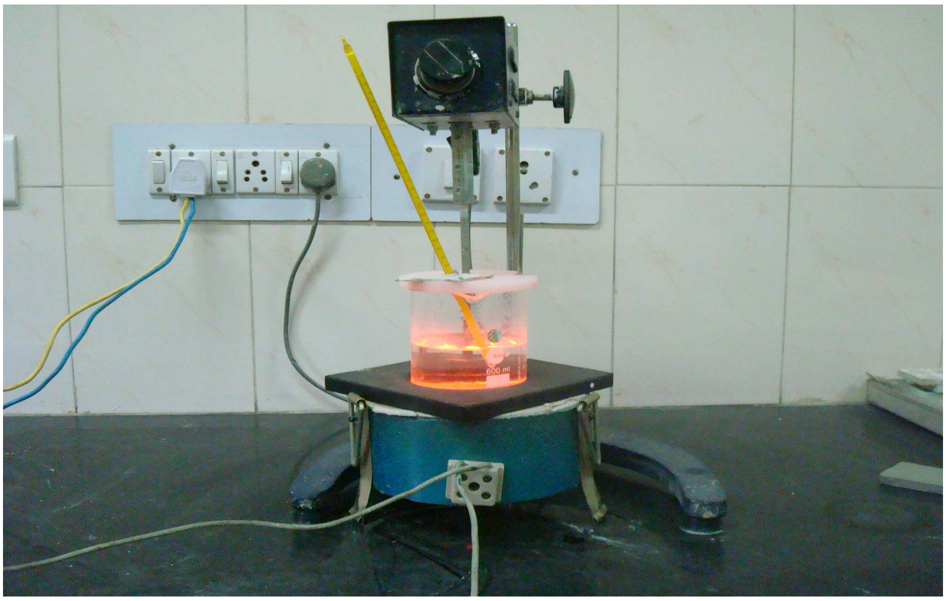

Figure: 4 Experimental Set up

Various schedules of experiments have been made. Initially a fixed quantity of water is boiled at 100 ˚C without applying any coating inside the heater plate. When the water reach its boiling point not down how much time take it for boiling. After doing that uncoated electric heater plate is replaced by ceramic coated electric heater plate and experiment is repeated, where the coating thickness is gradually increased to observe effect of coating thickness. In this way, the above experiment carried out in the laboratory has been repeated to find out variations, if any. The time of boiling is recorded for each set of experiment and using the energy meter a rough calculation has been made to establish consumption of wattage in each case i.e with or without ceramic coating.

Figure 5- Electric Heater

Figure 6- Heater Plate

RESULTS AND DISCUSSION

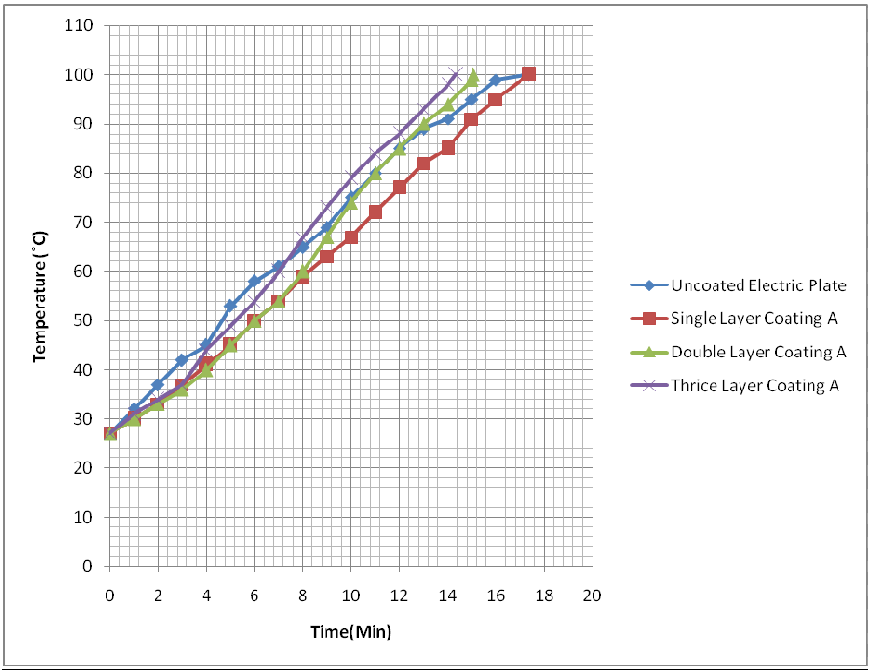

Figure 7: Sample "A" Coating graph

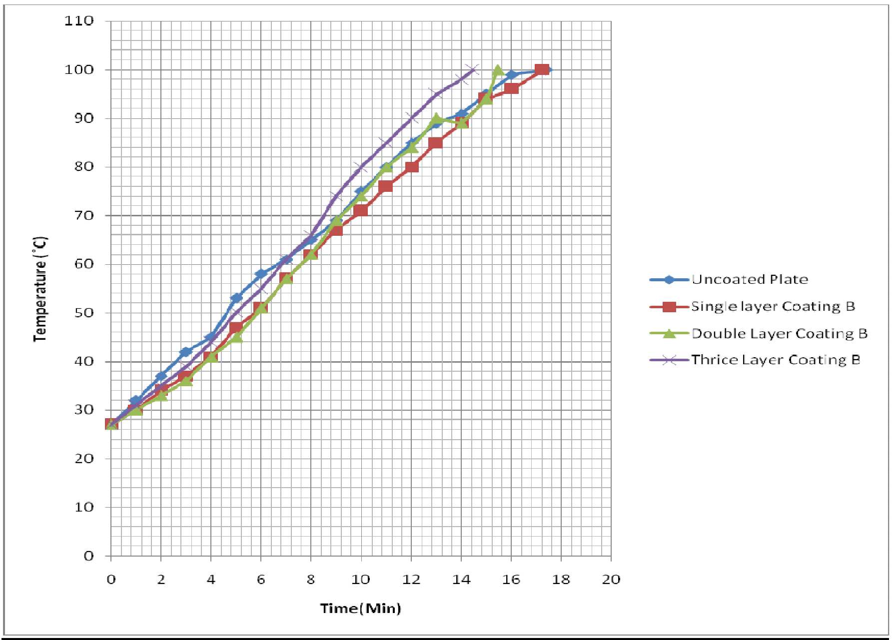

Figure 8: Sample "B" coating Graph

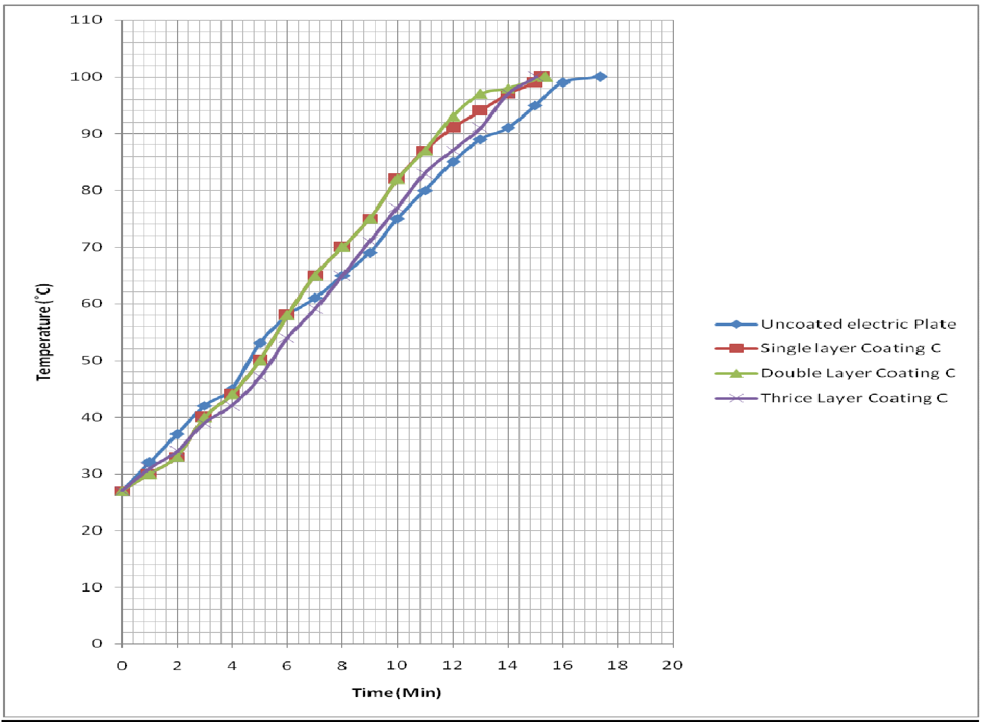

Figure 9: Sample "C" Coating graph

DISCUSSION

As per data shows in the graph, if we calculate the electricity consumption during performing the experiment, 0.445, 0.442, 0.383 and 0.366 unit consume per 17.36,17.32,15.02 and 14.35 minutes for uncoated, single double and thrice layer coating respectively So yearly Electricity consumption if we calculate than 18321 Rupees charge at uncoated electric plate. Instead of if we apply Single, Double and Thrice layer coating then 18198, 15768 and 15068 Rupees charged for consumption of electricity. So we conserve 0.678, 12.93 and17.36 % of electricity by applying Single Double and Thrice layer coating respectively. The other coating materials (sample B and Sample C) save the energy by applying thrice layer coating are 15.097% and 11.0% respectively.

CONCLUSION

The present study reveals that high emissivity coating on ceramic substrate for energy conservation. It was prove that when coating thickness increase, increase the temperature of heater system. For electric heater 11-17 % rise of heater performance was calculated when electric heater is coated. This increase in the thermal efficiency of the electric heater can be translated into an increase temperature, or a decrease in electric energy input.

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