HIGH EMISSIVITY COATING FOR ENERGY SAVING IN INDUSTRIAL FURNACES: CASE STUDY OF STEEL REHEATING FURNACE

BY

SONGSAK KLAMKLANG*, NIWAT ATHIWATTANANONT, NATTAPON JUMPIT AND NAVEE ANGSUPUTIPHANT

Texplore Co., Ltd., Member of Technology Business in SCG Chemicals Co., Ltd.,
1 Siam Cement Road, Bangsue, Bangkok, 10800 Thailand
*E-mail: songskla@scg.com

GAN YIMYAM, PONGSAK JARANSIRIPAISAN AND PIYA CHAIRAT[5]

Siam Yamato Steel Co., Ltd.
9/9 Soi G-5 Pakorn Songkronraj Road, Huay Pong, Muang, Rayong, 21150 Thailand.

ABSTRACT

More than 90% of energy liberated in steel reheating furnaces is transferred by radiation. Considering the scale and the importance of the steel reheating furnaces, an improvement of radiation heat transfer can lead to remarkable increase in the production yields or decrease in the fuel gas consumption.

The high emissivity coating was developed to maximize thermal efficiency of reheating furnaces by improving radiation absorptivity and emissivity of inner walls that affected on reduction of radiation in band of gas. While increase amount of additional radiation passes directly to billet inside the furnace.

The high emissivity coating material was successfully applied in steel reheating furnace that presented the appreciate reduction of fuel gas consumption. The application of high emissivity coating resulted on decrease of fuel gas consumption up to 6.5%.

Keywords: High emissivity coating, Steel reheating furnace, Hot rolling mill, Energy conservation and Fuel saving

1. Introduction

Energy problem is one of the most important issues seeming endless and continually affects all human beings directly. The price of crude oil and other energy sources in the global market has been increased from time to time [1]. In 2008, increasing demand for energy and rising energy costs throughout the world has inevitably increased the need for energy users to save or conserve energy, particularly among industrial entities. In many instances, industries that use fired heaters or furnaces have attempted to maximize furnaces efficiency to thereby reduce fuel consumption.

Fired heaters or furnaces are versatile heat transfer equipment in several industries such as refineries, petrochemicals, ceramic production and steelmaking [2]. The iron and steel industry is one of the largest energy-consuming manufacturing industries. Energy is consumed in steel production during the several stages in production process; raw materials preparation, iron making, steel making, finishing and heat treatment. Finishing process includes the operation of reheating the slabs, blooms, and billets and transforming them through hot and cold rolling steps into final products. Reheating furnaces are used to heat steel shapes to desired temperatures and suitable for plastic deformation in the rolling processes [3].

Reheating is a continuous process where the stock is charged at the furnace entrance, heated, and discharged. Energy is transferred to the items during their traverse through the furnace by means of convection and radiation from the hot burner gases and the furnace walls [3].

Due to high temperature of the combustion gases and the furnace walls, radiation is the predominant mode of heat transfer in the reheating furnace. Considering the scale of the reheating furnace in steelmaking process, even a small rise in thermal efficiency can be transferred into an important increase in the production yields or an important decrease in the required fuel input.

This work aimed to study the influence of application of high emissivity coating in reheating furnace. The results on thermal efficiency and fuel gas consumption in hot rolling mill process were obtained.

2. High emissivity coating

More than 90% of energy liberated in steel reheating furnace is transferred by thermal radiation. The application of high emissivity coatings in reheating furnaces is believed to improve the heat transfer from furnace to steel billets to effectively increase radiant heat transfer and save energy without compromising process reliability and safe operation. Higher emissivity corresponds to an increase in thermal efficiency. An increase in thermal efficiency attributed to high emissivity coatings in high temperature fired heater or furnace applications results in an increase in the furnace performance or output and/or a decrease in fuel consumption and overall energy demand. The benefits and advantages of high emissivity coatings have led to various research and development efforts over the years to improve the performance of high emissivity coatings [2].

High emissivity coating material developed to maximize furnace thermal efficiency to reduce fuel consumption in various industrial furnaces. High emissivity coating material contains materials capable of absorbing and re-radiating thermal energy and is designed to provide high coating surface strength, higher abrasion resistance, good thermal shock resistance, thermal expansion characteristics similar to their intended substrates, and adequate bond strength with the substrate [2].

In general, High emissivity coating maximizes and stabilizes the emissivity over varying process temperatures, thus promoting rapid and efficient heat transfer, uniform heating and extended refractory life.

3. Experimental

3.1 Materials

Most of high emissivity coatings contain materials capable of absorbing and re-radiating thermal energy [4]. Nevertheless, it still needs to be improved on coating adhesion properties for long service life over operating condition with several thermal shock cycles. There are some chemicals or substances that serve as binders or binding agents to promote a bonding between a coating composition and a substrate on which the coating composition is applied. Therefore, the formulation of water based coating for good adhesion, good thermal strength, high emissivity and less toxicity coating formulation was developed. The coating material was supply by Texplore Co., Ltd. Table 1 presents the general properties of high emissivity coating.

Table 1 General performance properties

Properties	Test methods	Value
Emissivity	Pyrometry	0.80 - 0.95
Surface strength	ASTM C1624-05 (2010)	> 20 N
Adhesion pressure	ASTM D3359-09	> 1000 psi
Thermal shock resistivity	Alternate heat/cold (Ambient-1,600 °C)	12 Cycles

3.2 Coating application

To ensure the thermal efficiency of high emissivity coating, the appropriate application procedures needs to be developed for each coating material.

Surface preparation

Surface preparation is the essential first stage treatment of a substrate before the application of high emissivity coating. The service life of high emissivity coating is significantly influenced by its ability to adhere properly to the substrate materials. When repairing an existing brick or refractory materials, make sure that removal all deteriorated refractory and dust. Dust should be caused of delamination of coating layer.

Coating application

The spray coating of high emissivity coating is performed using spray gun.

Dry out and furnace startup

Coating material needs several hours at ambient condition for drying before startup of furnace.

3.3 Implementation in steel reheating furnace

The coating material was applied in steel reheating furnace in hot rolling mill process with production capacity of 400,000 Ton annually. The billet size of 150x150 mm was used as reference size for energy saving evaluation.

4. Results and Discussion

Table 2 and 3 presents the comparison of operating and energy parameters in conditions of before and after high emissivity coating application, it was found that the reheating still maintained production capacity with slightly increase of production rate from 134 to 139 Ton/hr while the fuel gas consumption was decrease from 4,761 to 4,626 M^3/hr and specific energy consumption was decrease from 1,185 to 1,109 MJ/Ton of billet or saving of 6.5 % energy consumption.

The effect of high emissivity coating material on furnace wall on the furnace thermal efficiency should be explained on the basis of the radiation. Firstly, the application of high emissivity coating on a furnace wall implies that the amount of radiation energy that is reflected by the wall decreases. Secondly, the amount of radiation energy that is absorbed by the wall increases. As the furnace walls are insulated and the heat loss to the environment through the wall is small, more of this energy is re-radiated back in the furnace. Unlike the reflected energy that preserves its spectral character, the re-radiated energy is redistributed over the entire wavelength spectrum. Furthermore, only small part of the absorbed radiation is re-radiated within the range of absorption bands of the gas. Thus, in the event of a coated furnace, an additional amount of radiation passes directly to the targeting loads or billets with less amount of radiation being absorbed by the gas medium [2] that resulted on decrease of exhaust gas temperature from 704 to 692 °C.

Table 2 Comparison of operating parameters in conditions of before and after high emissivity coating application

Parameter	Before coating	After coating
Production rate (Ton/hr)	134	139
Charge temperature (°C)	80	62
Discharge temperature (°C)	1,245	1,226
Temperature difference (°C)	1,165	1,164
Cooling water flow rate (M^3/hr)	490	494
Inlet temperature (°C)	30	30
Outlet temperature (°C)	38	38

Table 3 Comparison of energy parameters in conditions of before and after high emissivity coating application

Parameter	Before coating	After coating
Fuel gas consumption (M^3/hr)	4,761	4,626
Heating value (BTU/ft^3)	894.3	894.3
Exhaust temperature (°C)	704	692
Production (Ton/hr)	134	139
Specific energy consumption (MJ/Ton)	1,186	1,109
Energy saving (%)	-	6.5

Table 4 is presented the energy distribution in reheating furnace in condition of before and after high emissivity coating application and the effectiveness of using high emissivity coating materials that could be confirmed by the increasing of billet heating from 43.6 to 49.6 % and decreasing of loss from exhaust gas from 40.2 to 34.0 %.

Table 4 Energy utilization in conditions of before and after high emissivity coating application

Segment	Before coating	After coating
Billet heating	43.6 %	49.6 %
Exhaust gas loss	40.2 %	34.0 %
Wall loss	5.6 %	4.5 %
Cooling loss	9.2 %	8.2 %
Scale	0.3 %	0.4 %
Other	1.1 %	3.3 %

5. Conclusions

High emissivity coating was successfully implementation in steel reheating furnace that resulted on reduction of energy consumption, improving furnace thermal efficiency and increasing production yields by maximizing thermal radiation capability. The utilization of high emissivity coating material is steel reheating furnace is not only solution for competitive advantage in steelmaking industry. Furthermore, it is the way for being eco-friendly of iron and steel industry to sustain business growth with care of environment.

6. References

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