EMISSIVE CARBON COATING FOR ENERGY-SAVING

Jun S. Yu[1], Yun S. Lim[1], Moon H. Han[2], Joon S. Kim[2], Sang K. Woo[2], In S. Han[2]
Jae C. Lee[1]
[1]Ceramic Engineering Dept., Myongji University, Yongin, 449-728, Korea
[2] Korea Institute of Energy Research, 305-600, Korea

Corresponding author e-mail address:jcl@mju.ac.kr

Introduction

It has been known that a high-emissivity furnace provides an energy-efficient alternative to a conventional furnace [1,2]. To improve the efficiency of a furnace, ceramic coatings with high emissivity are often applied to the interior of the furnace. The purpose of this paper is to show the amount of electrical energy-saving achieved by emissive carbon coating for a tubular vacuum-furnace. Alumina is important as a refractory material to heat the workload in controlled atmospheric conditions. In this work emissive carbon coating was applied to the interior of the alumina tube. Improvement on the energy consumption to heat up the coated tube was investigated quantitatively by measuring vacuumed cavity temperatures and electric powers consumed by electric furnace.

Experimental

Emissive carbon coating was prepared using a carbon black powder and a phenolic resin binder. The binder is an alcoholic solution of phenolic resin. Carbon paste was formed with a 1:3 weight ratio of carbon black and phenolic resin. The emissivity coating was applied by painting the carbon paste onto the interior surface of an alumina tube with one end closed. The alumina tube of 30 mm outer diameter, 23 mm inner diameter and 150 mm length is embedded vertically in the center of the furnace body. The vacuumed cavity temperatures of the alumina tube with and without emissive carbon coating, and cumulated electric powers consumed by tube furnace were recorded and compared. The effect of emissive carbon coating on energy-saving was interpreted in terms of measured temperatures and electric powers.

Results and Discussion

In this work, total emissivity of a sintered dense alumina disk was measured in air using FT-IR spectrometer. An emissivity value of 0.75 was obtained at 500•. The composition of the alumina disk is identical to that of the tubular dense alumina used as a substrate material for emissive carbon coating. The total emissivity of carbon coating was 0.81 at 300•. It is well known that carbon and carbides are materials having a relatively high emissivity over the entire spectral range. It has been reported that total normal emissivity of dense graphite at wavelengths between 0.6 and 6.8 ㎛ increases from 0.83 to 0.85 as the heating temperature is increased from 723 to 1013• in vacuum [3]. An extrapolation of the emissivity data down to 523• results the emissivity value of 0.81 for the graphite.

In Fig. 1 vacuumed cavity temperatures of tubular alumina with emissive coating are compared with those of uncoated one. As the temperature of the alumina increased from the room temperature to 1000•, vacuumed cavity temperature difference between the coated and the uncoated tube was increased up to 20•. As shown in Figs. 2, emissive carbon coated tubular alumina yielded an energy consumption of 559 Wh and a test time of 200 min to reach 1000□, while the uncoated tube gave 595 Wh. The emissive cabon coating saves approximately 6% in energy. These results indicate that heating energy and time can be saved for emissive carbon coated alumina when compared with uncoated one.

The Stefan-Boltzmann law gives the total power radiated at a specific temperature from an infrared source. The entire amount of infrared radiation at a specific temperature emitted from a given source at all associated wavelengths is written as:

$$R = e\,\sigma\,T^4 \tag{1}$$

where σ = Stefan-Boltzmann constant (5.67×10^{-8} $W/m^2/K^4$), e = emissivity value of the source, and T = surface temperature of the source in Kelvin.

Energy consumption results presented in Figs. 1 and 2 can be explained by Eq. (1). According to the Eq. (1), radiation energy R increases proportionally as a function of the surface temperature of the source T^4. Therefore we may conclude that energy savings by emissive coatings are greater at higher operation temperatures.

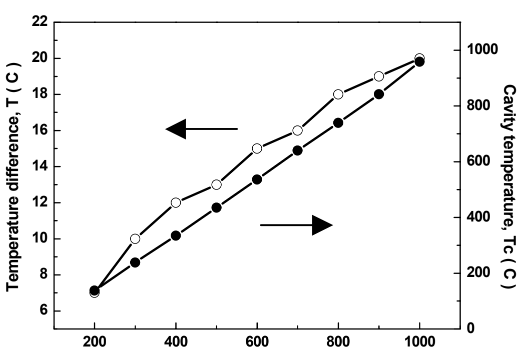

Fig. 1. Temperature rise of the cavity.

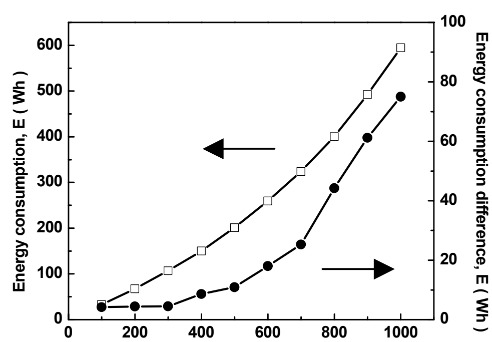

Fig. 2. Cumulative electric power,

Conclusions

By applying carbon coating to the interior of a tubular alumina, the amount of energy-saving achieved by the emissive coating was shown by measuring vacuumed cavity temperatures and electric power consumption of the tubular furnace. It is concluded that high-emissivity coatings reduce energy consumption of the vacuum furnaces due to the increased radiation heat transfer mechanism caused by increased emissivity. The fact that the energy-saving by emissive coatings are greater at higher operation temperatures are explained from Stefan-Boltzmann's law.

Acknowledgements

This study was supported by Korea Energy Management Corporation.

References

[1] Fisher G. Ceramic coatings enhance performance engineering. American Ceramic Society Bulletin 1986;65(2):283-287
[2] Burford RA, Fowler JB. Ceramic, black-body, high emissivity coatings for improved efficiency of fired heaters. Proceedings of the 2nd international conference on heat-resistant materials Gatlinburg (Tennessee, USA): 1995; 453-456.
v.In Walker PL Jr., editor. Chemistry and Physics of Carbon, Vol. 1, New York: Marcel Dekker, 1965:265-266.
[3] Neuer N. Spectral and total emissivity measurements of highly emitting materials. International Journal of Thermophysics 1995;16(1):257-265.